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INTRODUCTION.

THE extended study of the principal insect pests of the Sal, *Shorea robusta*, was included in the Triennial Programme of the Forest Zoologist, drawn up by the Board of Forestry at Dehra Dun in 1913. In the course of investigation it became evident that the Sal is subject to attack by a group of shot-hole and pin-hole borers belonging to the Coleopterous families Platypodidae and Ipidae, which cause considerable technical damage to its timber. During the three-year-period 1912-13—1915-16, the life-histories of some twenty-five species of shot-hole and pin-hole borers have been under observation and the economic status of the majority of species has been determined. It was originally proposed to record the results of the enquiry in the form of a memoir on the life-histories of the shot-hole borers of Sal, but the outbreak of war in August 1914 rendered this impossible. The work of identification and description of new species is in progress in collaboration with European specialists, but, as two are enemy subjects and the third is at present on military duty, their assistance is no longer available.

It is the purpose of this Record to give an account of the life-history and economic importance of one species of shot-hole borer, *Diapus furtivus*, Sampson, which has attained a certain amount of notoriety in connection with the death of Sal in Bengal, and which also may serve as a type of the life-histories and habits of this little-known group of borers. Accounts of the remaining species cannot be published until the confusion which exists as to their identities has been removed.

INDIAN FOREST RECORDS.

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THE LIFE-HISTORY OF *DIAPUS FURTIVUS*, SAMPSON (*Platypodidae.*)

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PREVIOUS HISTORY OF THE SPECIES.

The first specimens of the insect were taken by Mr. E. P. Stebbing in Sal trees in Assam, and are referred to in Forest Bulletin No. 11, "On some Assam Sal insect pests" (Stebbing,* 1907, p. 42) under the name of No. 23, *Diapus* sp. (238—1906), and an illustration of the beetle is given on Plate VI, fig. 10. Further specimens were taken in Sal in the Central Provinces in 1909.

In December 1912 Mr. J. R. P. Gent, Assistant Conservator of Forests, sent specimens of this beetle to Dehra Dun with a report that a large number of Sal in Buxa Division, Bengal, were dying from an unascertained cause, and that the dead trees were found to be full of larvae and beetles of this species. Sometimes isolated trees were attacked, and sometimes three or four trees fairly close together; the mortality was not confined to one block but occurred scattered throughout the division.

The material mentioned above was examined by Colonel Winn-Sampson, at the British Museum and assigned by him to two new species of Platypodidae, *Diapus furtivus*, n. sp., and *Diapus mirus*, n. sp. (Winn-Sampson, 1913, pp. 450—452), but as the writer has pointed out in another paper (Beeson, 1915, pp. 298—299) one species only is represented, *Diapus mirus* being the female of *Diapus furtivus*.

* All references will be found under author and year in the Bibliography at the end.

Mr. Stebbing in his recent book on Indian Forest Coleoptera (Stebbing, 1914, pp. 630—633, figs. 398, 399), refers to the insect under both specific names, and gives a short account of the method of oviposition. The correct synonymy of the species is given below, on page 5 of this Record. Further reports of damage assigned to this species were received from the Divisional Forest Officer, Jalpaiguri, Bengal, in August 1913 and from the Divisional Forest Officer, Buxa, Bengal, in October 1913.

Investigations in Bengal in 1913.

At the request of the Conservator of Forests, Bengal, the writer visited Buxa and Jalpaiguri Divisions in November-December 1913, and commenced investigations into the life-history of the borer and its connection with the dying-off of Sal in the Duars Sal forests. The chief result of the enquiry showed that the borer, while apparently causing the death of Sal trees of 3 feet girth and upwards in a very striking manner, was nevertheless not the true cause of death, but a secondary factor only. It was determined that the beetle is unable to establish itself in perfectly healthy trees, but requires trees weakened by disease and practically on the point of death to complete an attack successfully. If an attack is made on a healthy Sal, the tree at once reacts by a flow of resin and drowns the beetle before it reaches the sap-wood. Even in trees considerably reduced in vigour by defoliation, creeper-stifling, etc., the beetle fails to establish itself. Moreover, certain aspects of its breeding habits, the development of the ambrosia fungus on which it feeds, the absence of attack in the lower part of the bole in the early stages, etc., indicate that a definite state of unhealthiness is required.

A note on the enquiry was submitted to the Conservator of Forests, Bengal, (Forest Zoologist's No. 263-51 of the 9th April 1914) but it was considered that the case for the non-culpability of *Diapus furtivus* was not established with sufficient certainty for general acceptance, and the Local Government of Bengal desired that the enquiry should be carried further.

Investigations in Bengal in 1914-15.

The writer accordingly visited the Sal areas of Jalpaiguri and Buxa Divisions again in December 1914 and January 1915. The enquiry was carried out on somewhat different lines, with the intention of determining in what proportion the various species of Sal insects occurred

in dying trees, and to what extent each species could be considered primary. All dying Sal, and all dead Sal which had died not more than six months previously, were thoroughly examined for insect work of all kinds. In the majority of cases, the trees were felled and barked for their whole length and the roots uncovered. When not felled, the trees were examined by climbing and partial barking. The following forests were visited and groups of sample trees taken in each. *Jalpaiguri Division*—Panjora, Khariarbander, Goramara, Apalchand, Katambari, Muraghat, Kuntimari. *Buxa Division*—Mendabari, Chilarpata Poro, Rajabhatkhawa, Raidak, Damanguri. The results of the enquiry are of interest, not only as determining the cause of mortality in Jalpaiguri and Buxa Divisions, but also as suggesting the probable relative importance of Sal-infesting insects as pests in normal Sal forests.

The data obtained show that dying Sal trees are subject to the attack of some twenty species of bark and wood-boring beetles, generally associated in groups of three or four species, with a normal preponderance in number of one species over its associates. This may be attributed to the early arrival of one species, which is able to establish over the greater part of the bole before the swarming of the associated species occurs. The sample trees grouped, according to the prevalence of the more numerous species, give the following percentages :—

TABLE I.

INCIDENCE OF SPECIES OF SAL BORERS IN BENGAL, 1914-15.

1	Trees with insects absent at time of death			36
2	Trees with insects present at, or shortly after, death . . .			64
	(a)	*Hoplocerambyx spinicornis*, Newm.	30	
	(b)	*Diapus furtivus*, Samps.	16	
	(c)	*Xyleborus major*, Steb.	5	
	(d)	Either a, b, or c, associated with— *Sphaerotrypes siwalikensis*, Steb. . . . . . *Xyleborus fallax*, Eichh. . . . . . . *Xyleborus andrewesi*, Bldfd. . . . . . . *Platypus curtus*, Chap. . . . . *Diapus quinquespinatus*, Chap.	13	

In addition to the species given in the table above, the following commonly occurred, but usually as late arrivals after the establishment of one of the former group :—

Ipidae : *Xyleborus aplanatus*, Wich.
,, *laticollis*, Bldfd.
,, *parvulus*, Eichh.
,, *perforans*, Woll.
,, *schlichii*, Steb.
,, *semigranosus*, Bldfd.
,, *submarginatus*, Bldfd.
,, n. spp.
Eccoptopterus sexspinosus, Motsch.
Platypodidae : *Crossotarsus bonvouloiri*, Chap.
,, *saundersi*, Chap.
Platypus cavus, Stroh.
,, *cupulatus*, Chap.
,, *solidus*, Chap.
,, *pilifrous*, Chap.
Cerambycidae : *Dialeges pauper*, Pasc.
Chlorophorus n. sp.
Xylotrechus buqueti, Lap et Gory.

and several unidentified species of Curculionidae and Brenthidae.

It will be seen that the species most numerously met with is *Hoplocerambyx spinicornis*, while *Diapus furtivus* occurs in a very small proportion of the dead trees.

It would appear logical to conclude that the death of the tree was due to that species of insect which attacked first, but, as is shown below, in the greater proportion of cases. the insect is of secondary importance and a primary factor exists to which the death of the tree can be assigned. At the suggestion of Mr. R. S. Hole, Forest Botanist, the writer examined the roots of Sal which had died in the Duars forests for signs of disease, and found that in very many cases they were attacked by a fungus *Polyporus Shoreae*, Wkfld., which causes complete rotting of the root-system below soil level but gives little sign of its presence above ground. The root-fungus has since been found to be extensively distributed in Bengal and Assam Sal areas. Its economic importance is discussed by the Inspector-General of Forests in his Inspection Note on the Buxa and Jalpaiguri Forest Divisions (Hart, 1915 pp. 2—3) and by the Conservator of Forests in the Annual Progress Report on Forest Administration in Bengal for 1914-15, and it is only necessary

to remark here on its connection with insect pests. The diseased or dying state of the roots produces the condition of unhealthiness in the tree, which is essential for successful attack by insects. With the greater part of its root-system put out of action the tree is unable to offer resistance to a heavy attack by secondary borers and succumbs rapidly.

The chief point established by the investigations recorded above indicates that *Diapus furtivus* is not primarily responsible for the dying-off of Sal in Bengal, as was supposed at the commencement of operations, but that it is a member of a group of borers which attack dead and dying Sal, and under normal conditions is a secondary pest. Its economic status as a secondary pest in Sal forests is referred to on page 27.

Synonymy of the Species.

Diapus furtivus, Sampson. Fam. Platypodidae. Coleoptera.

Diapus sp., Stebbing, Forest Bulletin, No. 11, 1907, p. 42; Plate VI, fig. 10.

Diapus furtivus, Sampson, ♀ ♂ (lege ♂ ♀); Ann. Mag. Nat. Hist., Ser. 8, XII, 1913, pp. 450—451.

Diapus mirus, Sampson, (lege ♀), *loc cit.*, p. 452.

Diapus furtivus, Stebbing, Indian Forest Insects, 1914, pp. 630—632, fig. 398 (lege ♂).

Diapus mirus, Stebbing, *loc cit.*, p. 633, fig. 399 (lege ♂).

Diapus furtivus, Beeson, Indian Forester, XLI, 1915, pp. 298—299.

Diapus furtivus, Beeson, Indian Forester, XLII, 1916, pp. 222—224, Plate 16.

Diapus furtivus, Gravely, Records of the Indian Museum, XI, vi, 1915, p. 504.

Distribution.

The species appears to be distributed uniformly through the Sal forests of the Sub-Himalayan tract and of Central India, though more information is available as to its prevalence in the former region. Specimens in the Dehra Dun collection originated from the following forest divisions :—

ASSAM.—Garo Hills, Goalpara.

BENGAL.—Jalpaiguri, Buxa, Tista, Darjeeling.

UNITED PROVINCES.—Lansdowne, Gonda, Kheri, Ramnagar, Siwalik.

CENTRAL PROVINCES.—Mandla.

Food Plant.

The species is known only from the Sal (*Shorea robusta*), although many of its associates in Sal are known to attack *Terminalia tomentosa*, *Dalbergia Sissoo*, *Bombax malabaricum* and other trees.

DESCRIPTION OF THE INSECT.

The following general descriptions of the stages of the insect and the figures of the same on Plate I are given, with the object of facilitating recognition in the field at any stage in its development. Detailed anatomical descriptions will be given in a future paper on the Platypodidae.

The Adult. (Plate I, figs. 1 & 2.)

Male (fig. 1 × 12). The sexes are dimorphic and easily recognizable. The male beetle is 3·5 mm. to 4 mm. in length, cylindrical, shining. Head and prothorax black; elytra yellowish-brown with the apical third dark brown; legs yellowish-brown, long, with fine elongate tarsi. *Head* punctate with the front slightly concave, and the antennae elbowed, terminating in a flattened oval club. *Eyes* large, pear-shaped. *Thorax* oblong with a very short basal median line, on each side of which are groups of 4 or 5 pores. *Elytra* feebly punctured in lines; the apical margin of each elytron is armed with 5 blunt flat teeth-like processes, which conjointly produce an embattlemented appearance at the edge of the elytra. A group of minute pores near the outer apical margin of each elytron. The *Abdomen* is transversely convex with the last segment deeply concave, punctured, and sparsely covered with short yellow hairs.

Female (fig. 2 × 12). Similar to the male in general form and coloring but differing in the following respects. *Antennae* inserted in a line parallel with the upper edge of the eyes. *Front* of the head with a conspicuous brush of yellow hairs made up of four groups. From the anterior edge of the front the bunches of hairs extend upwards and curving backwards over the whole of the front meet the top of the head. Between the eyes are two large clusters of similar hairs, also divided into groups, the inner pair of which extend straight out from the front but are slightly bent downwards the tips; the other two groups are twisted outwards round the first pair and then cross in the middle of the front. *Prothorax* with a short median line on each side of which are groups of 11 or 12 large pores. *Elytra* with the apical margin rounded and not dentate.

The frontal brushes are found only in the young beetle and are absent in beetles which have bored into the wood.

This species is easily recognizable from other shot-hole borers of about the same size, found in Sal, as it is the only species of its size, with the elytra coloured yellow in the basal parts and dark brown in the apical parts.

Relative proportion of the Sexes.

There appears to be no record of the proportion in which the sexes of the species of Platypodidae occur under normal conditions and it is of interest to give the following figures obtained for *Diapus furtivus.*

In a brood of 1,090 individuals bred out from Bengal material the proportion was :—Males 59·2 %, Females 40·8%.

From two lots of material originating from the United Provinces the proportion was :—Males 59·5 %, Females 40·5 %.

In the remaining breeding cage records the preponderance of males over females varies from 10 to 20 %.

Observations made in the field in Bengal in 1913-15 confirm these figures, but rather divergent results were obtained by collection of beetles on the wing swarming round a newly felled tree, which tend to show that the females are more readily attracted to the host tree and appear first on the scene, being followed later in the day by the males.

PROPORTION OF SEXES TAKEN ON WING AT TRAP-TREE.

Date of capture.	Time of day.	Percentage of individuals.	
		♂	♀
January— 14th . .	Morning	28	72
17th . .	Afternoon	48	52
18th . .	Late afternoon	55	45
19th . .	Early morning	13	87

The Egg. (Plate I, figs. 5, 6 × 24.)

The newly laid egg (Plate I, fig. 5×24) is broadly oval, pearly white and shining. The shape changes with maturation and when nearly

ripe is oblong with rounded ends (Plate I, fig. 6×24). The colour darkens to a dirty brown and the segmentation of the contained larva is clearly visible. The mandibles, maxillae and palps show edges of brown chitin.

The Larva. (Plate I, figs. 7, 8, × 18 and × 12.)

The young larva (Plate I, fig. 7×18) is white, oval, 1—2 mm. long, legless, transversely wrinkled; dorsal surface convex, ventral surface flat; integument of body minutely shagreened, and bristle-bearing; prothoracic segment not differentiated as in later stages.

The older stage larva (Plate I, fig. 8×12) is white, cylindrical, 6—7 mm. long, legless, transversely wrinkled with well marked head and 12 body segments. *Head* white; mandibles brown edged with black; maxillae light brown. *Prothorax*, 1st segment transversely swollen and stouter than the succeeding segments; integument slightly thickened dorsally and bearing two transverse plates of chitin on either side of the median line, strengthened with 7 or 8 diagonal ridges, alternately bifurcate (Plate I, fig. 9). *Stigmata* 9, on 1st thoracic and 1st to 8th abdominal segments, each bordered with a plain ring of chitin. *Abdomen* with undersurface with numerous longitudinal wrinkles, crossing the segmental wrinkles, and forming isolated calli, each bearing a small chitinous tubercle surmounted by a short bristle. *Anal* segment truncate, with a short median tubercle and a few short bristles.

The Pupa. (Plate I, figs. 10, 11, × 12.)

The pupa possesses the general form and size of the adult, white, 5—6 mm., with legs and wing pads folded beneath the body and the abdominal segments exposed; 1st and 2nd pair of *legs* above the elytra on the ventral surface of the body, 3rd pair covered by the wing pads and elytra all except the terminal tarsal joints. *Abdomen* with segments furnished dorsally each with a row of minute chitinous teeth. Female (Plate I, fig. 11×12) with the frontal brushes enclosed in a membrane medianly divided into two lobes.

LIFE-HISTORY AND HABITS OF THE INSECT.

Swarming.

The beetles fly during the day in full sunshine and are attracted to Sal trees in a suitable condition for attack. Such trees are newly

felled trees on felling areas, fresh wind-falls, trees on the point of death, or very much weakened by disease or the attack of primary insects. The flight is weak and jerky and the beetles may easily be captured in a net or open killing-bottle. Both sexes swarm at the same time, though there is a tendency towards the earlier emergence of the males. The swarm periods are not sharply marked, as the emergence of individuals of a brood goes on for several weeks and the broods of successive generations overlap (see later under Seasonal History). The beetles, on arriving at a tree, settle on the bark and run about actively searching, under flakes of bark and in crevices, for a suitable site for the entrance tunnel. Stebbing (1914, p. 631) makes the following comment in this connection. "This little beetle differs from most platypids owing to its great activity." In the experience of the writer, however, *Diapus furtivus* does not appear to differ much from its associates in the matter of activity during the flight period. All Platypodidae which attack the Sal, are able to progress actively over the bark surface, and it may be noted that the period, prior to the boring of the entrance tunnel, is practically the only occasion on which the beetles make use of their tarsi. When living inside the tree and moving about in the galleries the long slender tarsi are folded back behind the tibiae and the beetle walks on the spurs at the apices of the tibiae. If Platypodid beetles are removed from their galleries, after they have lived in them for several weeks, they are found to be very helpless on their legs and appear to have lost the power to straighten out the tarsi. In many cases the tarsi are missing or have lost three or four joints.

The Entrance Tunnel and Wax-Tube. (Plate II, figs. *a*, *b*.)

The longitudinal cracks in the bark are invariably chosen, in the first place, for the site of the entrance tunnel, but, in the case of a heavy attack, entrance holes are bored on the flat interspaces as well. From 20 to 30 holes may occur in the same vertical line of a foot in length, but, while the distance between two holes is often less, the average is half an inch.

The entrance hole of this species is marked by a curious structure which, with one exception, is unique. Projecting from the bark for a distance of $\frac{1}{8}$th to $\frac{1}{4}$th of an inch and in direct continuation of the walls of the tunnel is a slender tube of white wax of papery thickness, finished off smoothly on the inner and outer surfaces (Plate II, *a*, *a*). The nearest analogous structures are the pitch tubes of the North American bark-beetles of the genus *Dendroctonus* and the ring of gum and wood-dust surrounding the entrance holes of some species of *Platypus* in India.

While these latter are more or less mechanically produced by the extension of the entrance burrow through the resin-flow from the host-tree, in the case of *Diapus furtivus* the wax-tube appears to be constructed by the beetle on a definite plan for a definite purpose. Its presence at the entrance to the galleries makes it more difficult for enemies to gain access, and it also renders the ejection of frass-particles more easy. We have seen the male of *Diapus furtivus* blocking up the wax-tube with its body, and effectually preventing the entrance of a crowd of small mites swarming outside on the bark. The projection of the tube, above the general level of the bark, also presents certain difficulties, in negotiation to the long-bodied predaceous beetles, which occur commonly in the galleries of other species of Platypodidae which do not possess this protective device. The only other species of Indian Platypodidae, which constructs a wax-tube, as far as the writer is aware, is *Diapus impressus*, Janson, which breeds in *Quercus incana,* in the Himalayas. The second species of *Diapus, D. quinquespinatus,* Chapuis, which finds a host in the Sal, curiously enough does not construct a wax-tube.

Construction of the Wax-Tube.

The wax is secreted by the male beetle only and the tube is constructed by him alone. The wax is secreted by a group of numerous minute pores situated in the apical third of each elytron. The fine glossy strands of wax lie flat on the surface of the elytron in a close band which curves in a right handed spiral and overlaps to form a small white disc about ·35 mm. in diameter completely concealing the group of pores (Plate I, fig. 3 $\times$ 20). Mr. Puran Singh, Chemical Adviser to the Forest Research Institute, who kindly examined these tubes, informs me that the wax is probably an ester of ceryl alcohol.

As soon as the construction of the entrance tunnel has made some progress, *i.e.,* has reached a length of $1\frac{1}{2}$ to 2 inches, the secretion of wax by the male begins. The tube, examined under a high-power lens, shows an imbricate structure due to rows of overlapping wax-scales. It is evident, therefore, that the beetle detaches the scales at intervals as soon as they are fully formed, and presumably moulds them into the walls of the tube by rotary movements of its body. One or two weeks is required to complete the construction of the tube, after which the secretion of wax ceases and is apparently not renewed if the tube should get broken, or crack, as it often does in the late stages of the development of the brood, owing to expansion of the bark layer.

It may be mentioned that the male of *Diapus impressus* also possesses a group of secretory pores at the apex of each elytron, which is more extensive than that of *Diapus furtivus.*

Construction of the Entrance Tunnel.

The initial excavation of the entrance tunnel (Plate II, *b*) in the bole of the host tree seems to be undertaken independently by the male or the female beetle, as specimens of either sex may be found alone in partially constructed tunnels. When a pair of beetles is found in freshly commenced tunnels, it is usually the female who is innermost, and it is very probable that, shortly after a pair has associated, the excavation work is taken over entirely by the female. After the entrance tunnel is completed the whole of the excavation of the gallery system is carried out by the female beetle. The long yellow brushes, borne on the front of the head of the female, are lost in the early stages of the excavational work, and no individuals found in tunnels, which have reached the sap-wood, still possess the brushes. Their function is obscure but is evidently only active from the time the beetle leaves her pupal cell, until she starts boring into the host tree. As the front of the head must be closely in contact with the terminal wall of the tunnel in order to bite through the fibres, the presence of a large tuft of bristles would be a hindrance. The possibility of the use of the frontal brushes, in connection with the transport of ambrosia fungus, is referred to on pages 14 and 15.

Pairing.

The act of pairing has not been observed ; it is equally possible that it takes place before flight in the old parent galleries, as after flight in the new entrance tunnel. One or two females captured out of a swarm were found on dissection to have ripe but unfertilized eggs in the ovaries. The female, however, lays eggs very shortly after boring into the tree, the first batch consisting of 5 to 15 eggs. The species is monogamous.

The Gallery Pattern. (Plate II.)

An examination of the literature on Platypodidae yields very scanty information with regard to the patterns of the gallery systems of various species. Of the genus *Platypus* some six or seven species from Europe, North and South America have been studied and their gallery patterns figured. One species of *Periommatus* from Africa has been

worked out, but on the Asiatic species very little information has been published. In another paper (Beeson, 1916, p. 219) the writer has pointed out that the gallery patterns of Indian species of ambrosia beetles of the families Platypodidae and Ipidae can be assigned to three general types ; and that the genera *Platypus* and *Diapus* exhibit gallery patterns of closely similar types, while the genus *Crossotarsus* is characterized by gallery systems constructed on a very different pattern.

In a normally developed gallery system of *Diapus furtivus*, the entrance tunnel is carried horizontally * and more or less radially through the bark, beyond the cambium layer to a depth of ½ an inch to 1½ inches, according to the thickness of the sap-wood zone. The gallery then curves rather sharply to the right or left, or bifurcates in both directions, and the remainder of the system is continued, in a horizontal plane, in curves nearly coinciding with the increment rings. In branchwood or stems of small dimensions, the main gallery (Plate II, *c*) may be continued completely round the circumference, but in the bole of large trees, and where galleries are crowded, the work of several beetles in the same plane coalesces, and a somewhat intricate zone of tunnels forms a girdle to the heartwood. From the main gallery short branch galleries (Plate II, *d*) take off at a slight angle, and cease after reaching ¾ of an inch in length, but are sometimes prolonged as secondary galleries running parallel to the main gallery for 2 or 3 inches. In addition to the secondary galleries there are several short bifurcate branches, which usually occur on the inner side of the main gallery and lie just within the heart-wood. Attached in a vertical plane above and below each of the arms of the bifurcate galleries, in close groups of 5 to 7, are small cells of ⅜ of an inch in length in which pupation of the larva takes place (Plate II, fig. *e*).

Development of the Brood.

On completion of the entrance tunnel, the first batch of eggs is laid in the tunnel and the female proceeds with the excavation of the main galleries, while the male remains at the entrance preparing the wax-tube. The eggs are left to hatch apparently without any special care by the parent beetles. Moreover, they are constantly shifted about, by the passage to and fro of the mother, while engaged in removing the particles of wood fibre resulting from the excavation of the main gallery. The female lays more eggs at intervals, until as many as 40 may have

* In the description of the gallery pattern and elsewhere the terms "horizontal" and "vertical" should be taken to mean at right angles and parallel respectively to the central axis of the tree, and thus may be applied equally to a standing or recumbent tree.

accumulated before the first batch has hatched. It has not been possible to ascertain the total number of eggs laid by one female during the course of her life, but, from countings of families in more advanced stages of development, it is known that the total exceeds 100.

The newly hatched larva differs slightly in form from the older larva but in all stages it is remarkably active and able to travel throughout all the galleries as fast as the parent beetles. The young larva uses its jaws as well as its abdomen for locomotion and progresses along the walls of the tunnel without difficulty. After two or three moults it has grown large enough to touch the whole circumference of the tunnel with its body and uses the rows of tubercles on the abdomen and a narrow chitinized plate on the thorax as means of propulsion. The larvae spend their lives wandering about the galleries, feeding on the sap and the food fungus, which grows on the walls. They take no part in the excavation of the galleries.

Food Material.

The Platypodidae, like the genera *Xyleborus* and *Corthylus* of the family Ipidae, are true ambrosia beetles, *i.e.*, the principal food of the larvae is a fungus, the ambrosia, which lines the walls of the brood-tunnels in a thin felt-like layer of mycelium and clusters of cells. The ambrosia of *Diapus furtivus* is not very abundantly developed and is frequently absent from some of the branch galleries. It appears as a light grey layer of variable thickness covering the surface of the galleries, which rapidly become black in color. The black stain penetrates into the surrounding wood tissue and forms a zone $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in width on either side of the gallery. The black stromatic growth of a fungus penetrates the wood tissue and blocks up the vessels and medullary rays (Plate II, *f*).

The discoloration appears to be connected with the ambrosia fungus, but, whether due to it or an associated species, has not been determined. The newly excavated galleries are not discolored but, in the course of a week or two, the stain makes its appearance and the width of the blackened zone gradually increases with the age of the gallery. It may be pointed out that the discoloration is characteristic of the galleries of *Diapus furtivus*. Many other shot-hole borers associated with *Diapus furtivus* in Sal, *e.g.*, species of *Xyleborus*, show no discoloration of the woody tissues near their galleries, while species of *Platypus*, *Crossotarsus* and *Diapus quinquespinatus* exhibit it in a much less marked degree.

The ambrosia fungus does not appear to form the entire food of the larvae, but is supplemented to a certain extent by sap-flow from the intersected vessels of newly excavated tunnels.

Transport of the Ambrosia.

The transport of the spores of the ambrosia fungus from the old host-tree to the new by the migrating swarms of ambrosia beetles is a subject which has attracted the attention of several observers, and has received diverse explanations. Hubbard (1897, p. 11) pointed out that the ambrosia does not make its appearance by accident or at random in the galleries of the beetles. Its origin is entirely under control of the insect, who cultivates it on specially prepared beds or layers of wood-dust. Schneider-Orelli (1913) has shown that, in the case of *Xyleborus dispar*, the ambrosia spores are carried in the crop of the female beetle and subsequently regurgitated on commencing the construction of the new galleries. Strohmeyer (1911, pp. 104—105) found that the group of brushes and processes on the front of the head of the females of *Mitosoma chapuisi* and *Spathidicerus thomsoni* are used for the transport of ambrosia spores.

In the case of the female of *Diapus furtivus*, it has been observed that the groups of brushes on the head similarly serve for this purpose. The writer has found small masses of vegetable cells inside the cavity formed by the overlapping clusters of hairs, which stain with Cotton Blue and are undoubtedly ambrosia cells (Plate I, figs. 4 × 20). The individual hairs are barbed and movement of the beetles up and down the galleries containing spore-bearing ambrosia would result in the mechanical collection of a mass of spores sufficient to start a culture in the new home. There is a second method of transportation of the ambrosia possessed by *Diapus furtivus*, which is also shared by a large number of species of Platypodidae, but does not appear to have been commented on previously. The large pores, situate in groups of 11 and 24 on the prothorax of the male and the female of *Diapus furtivus* in the living insect, are filled each with a globule of colorless glistening matter of fatty consistency. The globule is evidently secreted by the numerous minute ducts situate round the margin of the pore, and is held in place by a transverse bristle-like process which terminates in slender barbs. At the period of migration the pores are very conspicuous.

The secretion is sufficiently sticky to cause the liberated spores or spore-bearing bodies of the ambrosia fungus to adhere to the globule.

The writer has isolated ambrosia spores from the prothoracic pores of both sexes of *Diapus furtivus*, and has also observed the germination of the spores, while still attached to the globule of fat, after the beetle has commenced boring the entrance tunnel. The spores speedily become separated from the prothorax of the beetle once the insect is established in its tunnel, but, if galleries are opened up at the right moment the prothoracic pores may be seen by the naked eye very prominently marked in a white covering of newly grown mycelium.

It is worthy of note that the female is much better provided with facilities for transport of the food fungus than is the male.

Function of the Male Beetle.

It has been mentioned above that the whole of the excavation of the galleries is carried out by the female beetle, and that the male very rarely co-operates in this work nor apparently does he assist in the care of the larvae and culture of the food-fungus. He is invariably to be found within the first half inch of the entrance tunnel, head directed inwards, occupied in protecting the entrance from the intrusion of enemies and in ejecting particles of frass and excrement. The method of ejection is somewhat striking and again illustrates that the peculiarities in the anatomical structure of this species are adaptations for a special function. The male beetle collects particles of wood-fibres, pellets of excrement and waste material, and conveys them to the end of the entrance tunnel, by pushing backwards with the hind end of the body. A small heap of the material is collected in the concavity at the end of the abdomen (formed by the dentate and setiferous edges of the elytra and the ridged terminal segment), and expelled from the wax-tube with a sharp jerk. The muscular effort in ejection is very considerable, and is often sufficient to throw small pellets several feet into the air.

In consequence of this method of removing the frass, the waste material of the galleries is not accumulated directly at the base of the tree, but is scattered over the surrounding undergrowth in an area of several yards radius. A tree attacked by *Diapus furtivus* is readily recognizable from the layer of yellow dust which covers everything in its near neighbourhood.

The boring dust consists of white fragments of wood-fibres ejected unchanged while the construction of the galleries is in progress. Unlike that of many other shot-hole borers, *e.g.*, *Xyleborus major*, *Xyleborus semigranosus*, *Platypus curtus*, etc., the wood-dust is not pushed out

in a compact cylinder of coherent fibres, but scattered far and wide by the male beetle. When the initial stages of the galleries are completed and the larvae have commenced to feed, the nature of the ejectamenta changes. The wood-dust is replaced by larval excrement, which consists of small rounded yellow pellets, and is characteristic of the frass throughout the remainder of the period of infestation.

Maturation and Pupation.

As is shown later, it is believed that the period of the life cycle may occupy 10 weeks, but, as to the length of the various stages of the cycle, no observations have been made owing to the impossibility of breeding up isolated larvae under natural conditions.

When mature and ready to pupate, the larva retires to one of the short branch galleries on the inner zone of the gallery system and eats out a vertical cell at the extremity. The orientation of the cell longitudinally is directed by the run of the wood-fibres and is consequently not necessarily exactly in the vertical line, but may slope to either side of the vertical. All pupal cells in one group slope in the same direction. The cell constructed by the first larva is situated at the extremity of the branch gallery, and the second cell is constructed so that its centre is opposite the outer margin of the first cell; the third cell is constructed alongside the first, and the remainder are subsequently added in similar order, *i.e.*, $\frac{1,\ 3,\ 5,\ 7,\ 9,\ 11}{2,\ 4,\ 6,\ 8,\ 10}$ so that the youngest cell is at the extremity of the branch gallery and farthest from the main gallery. Plate I, fig. 12 shows ($\times$ 4) a group of pupal cells with the insects in successive stages of development.

All the pupae face with their heads towards the exit, *i.e.*, those situated above the branch-gallery with their heads downward, and those below the branch-gallery with their heads upward. The sex of the beetle is not influenced by this arrangement.

The larva is able to turn round in the pupal cell while excavating it and does so as its final action before sealing up the exit with a plug of wood-dust. It then casts its skin which is always to be found at the end of the pupal cell, and remains until mature. The pupal skin is then cast and the beetle slowly matures, while the integuments harden and the colours develop. It is not known how long this process takes or how long the immature beetle spends feeding in the galleries after it has emerged from the pupal cell.

The emergence of the whole brood takes place through the original entrance tunnel.

SEASONAL HISTORY.*

Seasonal History in Bengal and Assam.

In August 1914 logs of Sal attacked by *Diapus furtivus* were collected in Buxa Division, Eastern Bengal, by Deputy Ranger B. K. Kashta, and sent to Dehra Dun. The emergence records of two logs A and B are given below in Table II.

The tree (S. T. 56), from which the specimens were taken, stood in Compartment 18, Rajabhatkhawa Block, Buxa Range, Buxa Division, in an area of considerable mortality among the older trees. In January 1915, the writer visited the area personally and ascertained that all the trees had been attacked by the Sal root-fungus, and that their deaths were to be attributed primarily to that cause. The tree (S. T. 56) was noticed by the Ranger to be newly dead on 18th August 1914, and on examination early stage work of *Hoplocerambyx spinicornis*, and *Diapus furtivus* was found. Beetles of the latter species were collected on the bark and boring into the sap-wood. The tree was felled on the 29th August and a log about 18″ long, Log. A. (R. R. D. 62) was sent to Dehra Dun for breeding experiments. Beetles and eggs of *Diapus furtivus* and of *Sphaerotrypes siwalikensis* were collected at the same time.

On the 27th September 1914 the Ranger, at my request, sent a second log from the same tree. The emergence records from this log, B, (R. R. D. 65) are given in the Table below.

* The terminology of "seasonal, and life-history," "brood," "generation," etc., used in this bulletin is that proposed by Hopkins (1909, pp. 38—41) in his monograph on the genus *Dendroctonus*.

TABLE II.

INSECTARY EMERGENCE RECORD OF *Diapus furtivus* FROM BENGAL R. R. D. 62 (LOG A.) AND R. R. D. 65 (LOG B.)—1914.

Date of Emergence	Number of Individuals Log A.		Number of Individuals Log B.		Total Logs A & B.	Date of Emergence.	Number of Individuals Log A.		Number of Individuals Log B.		Total Logs A & B
	♂	♀	♂	♀			♂	♀	♂	♀	
October—						November—					
21st	..	..	3	1	4	18th	..	..	4	2	6
22nd	..	..	..	2	2	19th	1	..	9	5	15
23rd	..	..	1	1	2	20th	4	..	5	8	17
24th	..	..	..	1	1	21st	..	..	6	7	13
25th	..	..	7	3	10	22nd	..	..	7	5	12
26th	..	1	48	24	73	23rd	1	..	6	4	11
27th	..	..	36	30	66	24th	..	..	11	..	11
28th	..	3	31	13	47	25th	1	..	2	2	5
29th	1	..	39	22	62	26th	1	..	2	3	6
30th	..	..	33	14	47	27th	..	..	7	..	7
31st	3	..	38	21	62	28th	..	..	..	..	..
November—						29th	..	..	..	..	
1st	..	..	37	26	63	30th	..	..	2	2	4
2nd	1	..	21	31	53	December—					
3rd	4	1	27	9	41	1st	..	..	5	1	6
4th	..	2	26	25	53	2nd	..	..	1	1	2
5th	..	1	26	19	46	3rd	2	..	3	..	5
6th	3	..	20	24	47	4th	..	..	2	..	2
7th	4	2	24	9	39	5th	..	..	..	..	..
8th	1	1	13	10	25	6th	..	..	..	..	..
9th	2	..	11	8	21	7th	..	1	..	1	2
10th	..	..	18	15	33	8th	1	1	1	1	4
11th	..	..	11	16	27	9th	..	..	1	1	2
12th	1	2	10	14	27	10th	..	..	..	..	..
13th	..	2	5	14	21	11th	..	..	..	..	..
14th	..	..	15	8	23	12th	..	..	2	..	2
15th	..	..	8	10	18	13th	..	..	..	..	..
16th	..	..	6	5	11	14th	..	..	..	..	..
17th	..	..	11	21	32	15th	..	..	2	..	2

The figures in the table show that emergence of mature beetles commenced in the fourth week of October, and continued steadily until the middle of November, after which the daily numbers decreased and a weaker emergence occurred until the end of the month. In December a few belated individuals appeared irregularly during the first fortnight, the last emergence occurring on the 15th of the month. The tree was examined on the spot on 18th January 1915 and was found to contain no *Diapus furtivus.* A comparison of the two logs, one of which, A, was removed from the forest on the 29th August, and the other, B, on the 27th September, shows that, while the attack of *Diapus furtivus* commenced as early as the middle of August, the bulk of the swarms did not arrive at this particular tree until early in September. Assuming that the prolonged emergence period of 5 or 6 weeks is paralleled by an equivalent period of attack, it is evident that the period of development of an average individual from egg to flight is 10 or 11 weeks. The tree, however, remained in a favourable condition for the development of several broods throughout a period of 16 to 18 weeks.

The emergence records obtained under insectary conditions were confirmed by actual observations in the field in 1913 and 1915. In November 1913 the writer toured in Buxa Division, Bengal, and found *Diapus furtivus* abundantly throughout the month. The species was taken on the wing, swarming, egg-laying, and boring its galleries in the sap-wood. That the flight period is very prolonged may be concluded from the fact that while eggs and early stage larvae were found on the 12th November, in galleries which had been excavated to a length of 3 or 4 inches, large numbers of beetles were taken on the wing from the 14th to the 20th swarming round felled Sal trees.

Again, in December 1914, in the course of a tour in Jalpaiguri Division, Bengal, *Diapus furtivus* was found in various stages of development, on the 5th in a tree dead some months. In the upper part of the bole, where the attack usually commences, maturing broods of the borer were present with old larvae in the galleries, and pupae and young beetles in the pupal chambers, while lower down the bole less advanced stages were predominant.

Again, on the 13th December, in a tree known to have died in August (S. T. 10), the work of *Diapus furtivus* was found extending from the top to the bottom of the trunk. In the upper parts of the bole the broods had matured and the beetles swarmed, while the lower part of the tree still contained pupae and beetles in the pupal chambers. On the 15th December in a standing dead tree (S. T. 15), the borer was

met with mainly in the pupal stage. On the 20th, the beetle was taken abundantly on the wing round a recently dead tree (S. T. 16), the leaves of which had not yet fallen. The tree was badly attacked by *Hoplocerambyx spinicornis,* while earlier flights of *Diapus furtivus* had recently established in the upper part of the bole. On the other hand, in two dead trees (S. T. 17 and 18), examined in the same locality on the same date, the development of the borer was represented mainly by late larval and pupal stages.

At the end of the month, 25th-29th, swarms of *Diapus furtivus* were frequently met with. Logs freshly attacked by the borer were collected on 16th December and sent for breeding experiments to Dehra Dun. The emergence records (R. R. D. 76) show a fairly steady appearance of *Diapus furtivus* from the 10th of February to the 6th of March, *i.e.*, through a period of from 8 to 12 weeks after collection. As it is very probable that eggs were laid about a fortnight before, and after the 16th December the emergence dates agree with the assumption that the life-cycle occupies about 10 weeks. The Divisional Forest Officer, Darjeeling Division, Bengal, in December 1915 sent a Sal log from a tree felled on the 25th November 1915 in Tista-Takdah Range (R. R. D. 67). This was examined at Dehra Dun on the 28th December and early work of *Diapus furtivus* observed. The beetles had paired and commenced excavation in the sap-wood but no eggs had been laid.

In January 1915, the writer toured in Buxa Division, Bengal, and obtained the following field records :—On the 11th, in a tree which had died several months before (S. T. 55A), traces of completely matured broods of *Diapus furtivus* were recognized. All beetles had swarmed with the exception of a few stragglers. On the 15th, in a recently dead tree, which still retained the shrivelled leaves (S. T. 67), early work of *Diapus furtivus* with eggs and newly hatched larvae was found. A few days later, in another tree (S. T. 61), dead some months before, the late pupal stages of the borer marked the general stage of development. During this period swarming beetles were occasionally taken on the wing.

A similar development to this in Assam is indicated by the results obtained from the insectary records of specimens collected by Forest Ranger D. C. Ghosh in Guma Range, Goalpara Division, Assam. A tree attacked by *Hoplocerambyx* and shot-hole borers was felled in September 1915, and logs cut and despatched to Dehra Dun on 1st December 1915 (R. R. D. 61). The emergence of *Diapus furtivus* is given in the table below.

TABLE III.

INSECTARY EMERGENCE RECORD OF *Diapus furtivus* FROM ASSAM. R. R. D. 61—1915.

	♂	♀		♂	♀		♂	♀		♂	♀
December—			February—			February—			March—		
			14th .	1	..	2nd .	..	1	1st ..	1	..
18th .	..	3	17th .	1	..	3rd .	1	..	4th .	1	..
						4th .	1	..			
25th .	..	1	19th .	1	1	11th .	2	..	16th .	1	..
			23rd .	1	1	14th .	3	3			
			26th .	1	..	16th .	2	..			
			31st .	1	2	17th .	..	2			
						18th .	2	..			
						19th .	2	..			
						28th .	1	1			

The early stages of the attack of *Diapus furtivus* were noticed in this locality, Guma Range, Goalpara Division, at the end of January 1916 in a Sal tree felled in the year's coupe in December 1915. Here again the insectary emergences are paralleled by field observations.

The flight period of later broods, which appear in the hot weather, has not been determined for Bengal and Assam, but, that intermediate generations occur during the hot weather and early rains, can be deduced from the statement of Stebbing (1914, p. 631) to the effect that the beetle was very plentiful on the wing and boring into the bark of newly felled trees in the latter half of May 1906 in Goalpara Division, Assam. Further evidence is available from specimens collected by Forest Ranger B. N. C. Banerji in Apalchand Range, Jalpaiguri Division in July, 1913, and forwarded to Dehra Dun for observation (R. R. D. 10). Emergences occurred regularly from 22nd August 1913 to 18th September 1913.

TABLE IV.

Insectary Emergence Record of *Diapus furtivus* from Bengal, R. R. D. 10—1913.

Date of emergence.	Number of individuals.	Number of parasites.	Date of emergence.	Number of individuals.	Number of parasites.
	♂ & ♀			♂ & ♀	
August—			September—		
22nd . . .	3	1	8th . .	11	2
26th . . .	3	1	9th . .	9	..
27th . . .	8	2	10th . .	1	5
29th . . .	1	2	13th . .	3	2
September—					
1st . . .	5	7	15th . .	2	2
3rd . . .	2	1	18th . .	2	3
4th . . .	3	4	29th . .	2	..

The broods were heavily parasitized, 51%, by a chalcid which accounts to some extent for the shortened swarming period.

With this last record we are brought to the close of the annual cycle of the seasonal history of the species, as the broods emerging in August and September give rise to a second generation maturing in October and November. *cf.* Table II.

Seasonal History in the United Provinces.

In the United Provinces less evidence is available on the seasonal history, but there appears to be no very marked difference in the length of the life-cycle or in the succession and overlapping of generations.

In November 1915, the Divisional Forest Officer, Gorakhpur Division, Eastern Circle, sent a Sal log cut from a coppice tree, which was left standing isolated by a clear-felling during the previous season and which died during the rains (R. R. D. 60). *Diapus furtivus* emerged in small numbers from this log at Dehra Dun in the 3rd week in January.

At the end of January 1916, Mr. H. G. Champion, Assistant Conservator of Forests, Kheri Division, Eastern Circle, United Provinces, found mature beetles and larvae of this species in a wind-felled Sal, dead about 3 months, and sent a wood specimen to Dehra Dun, which yielded beetles in the 2nd week of March.

In the Siwalik Division, Western Circle, the writer observed *Diapus furtivus* swarming early in February 1914, and found eggs and paired beetles in the early stages of the sap-wood galleries on the 24th of the month.

A tree was felled on February 1916, in low-level Sal forest of the Trans-Sarda tract in Kheri Division, and a log straightway despatched to Dehra Dun (R. R. D. 98), which yielded beetles during April as detailed below.

TABLE V.

INSECTARY EMERGENCE RECORD OF *Diapus furtivus* FROM THE UNITED PROVINCES R. R. D. 98 - 1916.

Date of emergence.	Number of individuals.		Date of emergence.	Number of individuals.	
	♂	♀		♂	♀
April—			April—		
2nd . . .	1	..	10th . .	2	3
5th . . .	..	1	11th . .	..	1
6th . . .	2	1	12th . .	2	..
7th . . .	1	1	13th . .	..	1
9th . . .	..	1	15th . .	3	1

Seasonal History in the Central Provinces.

Of the seasonal history in the Central Provinces no information is forthcoming. Sal trees have been felled during the cold weather, December-April, in most of the Sal-bearing forests, and logs have been sent at intervals to Dehra Dun, but, with the exception of occasional pairs of beetles, no infestation, severe enough to be of use for experimental breeding purposes, has been obtained. Stebbing (1914, p. 631) states that a maturing generation was taken in the middle of April 1909 in

Mandla Division, and suggests that the eggs were laid late in February or early in March. At the same time beetles were found boring into newly felled trees and engaged in ovipositing.

Summary of the Seasonal History.

From the data given above, although disconnected and extending over a period of three years, it is possible to arrive at fairly definite conclusions as to the life-cycle and seasonal history of *Diapus furtivus*. We have stated that the length of the life-cycle from egg to mature beetle approximates to a period of 10 or 11 weeks, but that this period does not necessarily represent the length of a generation, since the oviposition period of the female is variable and the feeding period of the young beetle before swarming is also variable. The variation from the average is influenced directly by the degree of freshness of the infested timber, resulting from rapid or delayed evaporation of sap. In the former case, the periods of attack and of emergence are shortened, and in the latter case, they are lengthened, while the periods of development conversely are respectively extended and decreased.

Under the most favourable conditions, it would be possible for a theoretical series of five generations to occur, provided that freshly felled or dead timber is available at each of the successive swarming periods. Under normal conditions, however, it is unlikely that a complete series of generations is carried through in any one locality. Primarily the absence of suitable breeding material at the time of emergence of many of the broods results in failure to carry on to the next generation. The swarming beetles are forced to attack either living healthy trees, or dead and dry timber. In the former case, they rarely penetrate further than the outer layers of the sap-wood, where they are drowned in a flow of resin which invades the entrance gallery ; in the latter case, the scantiness of sap is insufficient to provide nourishment for the complete development of the larvae, which dry up in the galleries and die with the parent beetles. The variation, which occurs in any one brood, in the length of the periods of egg-laying, larval development and feeding period of the young beetle, destroys all possibility of recognizing in the forest a regular succession of generations, swarms, attacks, etc. It can be said with accuracy that, on any day during the rains, cold weather and early hot weather, it is possible to find in a Sal forest all stages of *Diapus furtivus* from the egg to the flying beetle. In a particular spot, and especially in a particular tree, it is true that one stage in the life-cycle may predominate numerically over the other

stages, but, in another locality and in another tree, the general stage of development represented will be quite different.

It is probable that, in the hottest months of the year, development is considerably retarded, if not entirely checked, though no definite aestivation may occur. There is, however, little evidence at present as to the state of activity during the hot weather.

Natural Enemies.

It is chiefly in the adult stage that *Diapus furtivus* is subject to the attack of natural enemies. During the great part of its life, within the tree, it seems to be remarkably well protected against predaceous and parasitic enemies.

Several species of Cucujidae, Colydiidae, etc., occur commonly as mature beetles under bark of Sal trees infested with shot-hole borers, but, to what extent they are predaceous on *Diapus furtivus*, and in what stages, remains to be worked out. Many of the species cannot be predaceous in the galleries as beetles, on account of the size and form of their bodies.

Many species are new and many have not been identified.

Colydiidae.

Xuthia sicana, Pascoe, *Microprius difficilis*, Grouvelle, occur commonly under the bark of Sal in the United Provinces forests.

Asosylus filiformis, Grouvelle, and *Asosylus* n. sp., occur in the galleries and appear to be direct parasites in Bengal.

Sysolus ? sp. A remarkable long tubular beetle, which occurs commonly in the galleries of *Diapus furtivus*, and is probably its most important predator.

Cerylon quadricolle, Sharp, observed occasionally in the galleries of other shot-hole borers.

Cucujidae.

Hectarthrum heros, Fahr. (Bengal, United Provinces, Central Provinces). Stebbing (1914, p. 116) mentions observing it eating *Platypus suffodiens* in Burma, and says *loc. cit.*, p. 623, that "its grubs enter the tunnels of the platypids and feed on the platypid larvae."

Cleridae.

Tillioera assamensis, Steb. Stebbing (1914, p. 632) states that this beetle is predaceous on *Diapus furtivus* and *Diapus quinquespinatus* in Assam.

Stignatium spp. Two species of this genus, at present unidentified, are predaceous in the adult stage on swarming beetles of *Diapus furtivus* in Bengal and the United Provinces.

Curculionidae.

Phaeomerus sundewalli, Boh. and one other species of *Phaeomerus* may be predaceous as beetles on *Diapus furtivus*, as they have been found several times in the galleries of the latter, by the side of, and apparently feeding on, dead male beetles.

Chalcidae.

A species of this family at present unidentified has been bred out from *Diapus furtivus* broods.

Formicidae.

Œcophylla smaragdina, F. is an important enemy of the beetle. A Sal tree round which beetles are swarming is usually occupied by an army of red tree-ants.

A beetle alighting on the bark is seized at once by a *smaragdina* worker. Although the thorax is crushed by the first grip of the ant's mandibles, the beetle is not carried off to the nest until it is quite dead. To effect this two or three ants seize the legs and wings of a beetle and stretch the nerve chords to the full extent until the beetle dies.

Nematoda.

Dr. Butler, Imperial Mycologist, Pusa, who examined some beetles of this species, informs me that he found parasitic nematode worms in the bodies of several.

Economic Importance.

Economic Importance as a Primary Pest.

In a normal healthy Sal forest, the damage, due to primary attack by this insect, is practically negligible. It is not able to establish successfully in a vigorous tree. Attempts to bore into the tree fail on reaching the sap-wood owing to the resin flow which occurs as a protective reaction on the part of the injured tissues.

Unhealthy and weakened trees are less able to withstand attack and may succumb, but it would appear that a very advanced state of unhealthiness is necessary. Trees defoliated for two or three years in succession, stag-headed and creeper-strangled trees, etc., are not as a rule killed by *Diapus furtivus*. Trees attacked by *Hoplocerambyx spinicornis* are usually infested with shot-hole borers also.

In the case of trees suffering from fungus diseases, as in the Bengal forests infested with *Polyporus Shoreae*, the effective attack of the

beetle causes the tree to die off in a rapid and striking manner. The first onslaught is made high up on the bole, just below the crown branches, and usually is not extended downwards to within less than 15 feet of the ground until the tree is dead. The actual death of the tree is due to the mechanical girdling action of the crowded galleries, combined with the extraction of cell-sap by the mycelium of the ambrosia fungus. The water-current, already weakened by the diminution of the effective root area, is cut off from the crown, and the leaves rapidly wither, turn brown, and, in the course of a few weeks, fall.

The economic importance of the beetle in this connection is affected by the length of time required by the root-fungus alone to kill off the tree, and varies directly with the number of years. If a tree, with one-half to two-thirds of its roots out of action, is destined to die within one year, the acceleration of its death, by shot-hole borer within that period, can be neglected. If, on the other hand, the diseased tree normally lingers for a period of five, or ten, or more years in the absence of insect attack, the economic status of the latter must be considered.

It is worthy of note that about twenty-five per cent. of the insect-infested Sal trees in the Duars forests contained *Diapus furtivus.*

Economic Importance as a Secondary Pest.

The technical damage due to this species takes the form of shot-holes and lines and stained wood defects in the sap-wood and outer heart-wood of timber. In badly attacked trees the outer two inches of heart-wood is perforated to such an extent as to render it useless.

In Assam and Bengal, the attack of shot-hole borers is more serious than in the United Provinces and the Central Provinces, and, according to the reports of divisional officers, the sale price of the timber is appreciably affected.

Control Measures.

The following preventative measures should be introduced and kept in force annually as a permanent protective operation. The measures have the advantage of protecting timber against the attacks, not only of *Diapus furtivus* but of all shot-hole and pin-hole borers, of bark beetles, and of the large longicorn borer, *Hoplocerambyx spinicornis.*

1. *Fellings.*—Trees, in annual coupes felled, should be barked at once, unless converted and removed from the forest within one month.

If allowed to remain unbarked for more than one month, the sap-wood also should be removed, wherever insects have commenced work.

The bark and sap-wood need not be burned, but, if possible, should be scattered or exposed to the sun.

Tops and branchwood over 18 inches girth, left on the felling-areas, should be treated in the same way as logs, *i.e.*, bark and sap-wood removed. This material forms the chief breeding ground of the borers, and the object of control measures is to reduce it as far as possible for the time and labour expended. In any case, at least 75% of the unsaleable material left on felling-areas should be treated.

2. *Isolated Trees or Groups.*—Recently dead, dying, or green attacked trees, met with in departmental operations, *viz.*, coupe-marking, cleaning, creeper-cutting, dry wood marking, etc., should be disposed of at once. If the early stages of the attack occur, immediate felling and barking will be effective, but if the insects have already penetrated to the heart-wood, *i.e.*, in trees dead three months and more, nothing practical can be done, except immediate conversion or removal of the logs to localities outside the forest.

Summary.

Diapus furtivus, Samps. is one of the shot-hole borers attacking Sal in the Sub-Himalayan and Central Indian Sal areas. It is able to kill off trees with diseased roots, but its attack is not fatal to trees weakened by defoliation, creepers, unsuitable local conditions, etc. It normally breeds in newly dead or felled trees and is particularly abundant in felling-areas and depôts. It is active throughout the year.

The beetles bore a system of galleries, in the sap-wood and heart-wood of Sal on a definite pattern, and bring up a brood of about 100 larvae in the galleries. The food of the larvae is not wood-dust, but an ambrosia fungus which grows on the walls of the brood-galleries, supplemented by wood-sap. The length of the life-cycle may be 10 weeks or more, but owing to the prolonged egg-laying period of the mother beetle, emergence of the brood is extended over a period of 5 or 6 weeks. It is not possible to determine the minimum number of generations from the field-data. There are no marked swarm periods as all stages of the insect are met with throughout the year.

Its chief economic importance lies in the technical damage to unbarked timber, which takes the form of shot-holes and lines and stained wood defects. It may be controlled by early barking on felling-areas, and the removal of newly dead trees in other parts of the forest.

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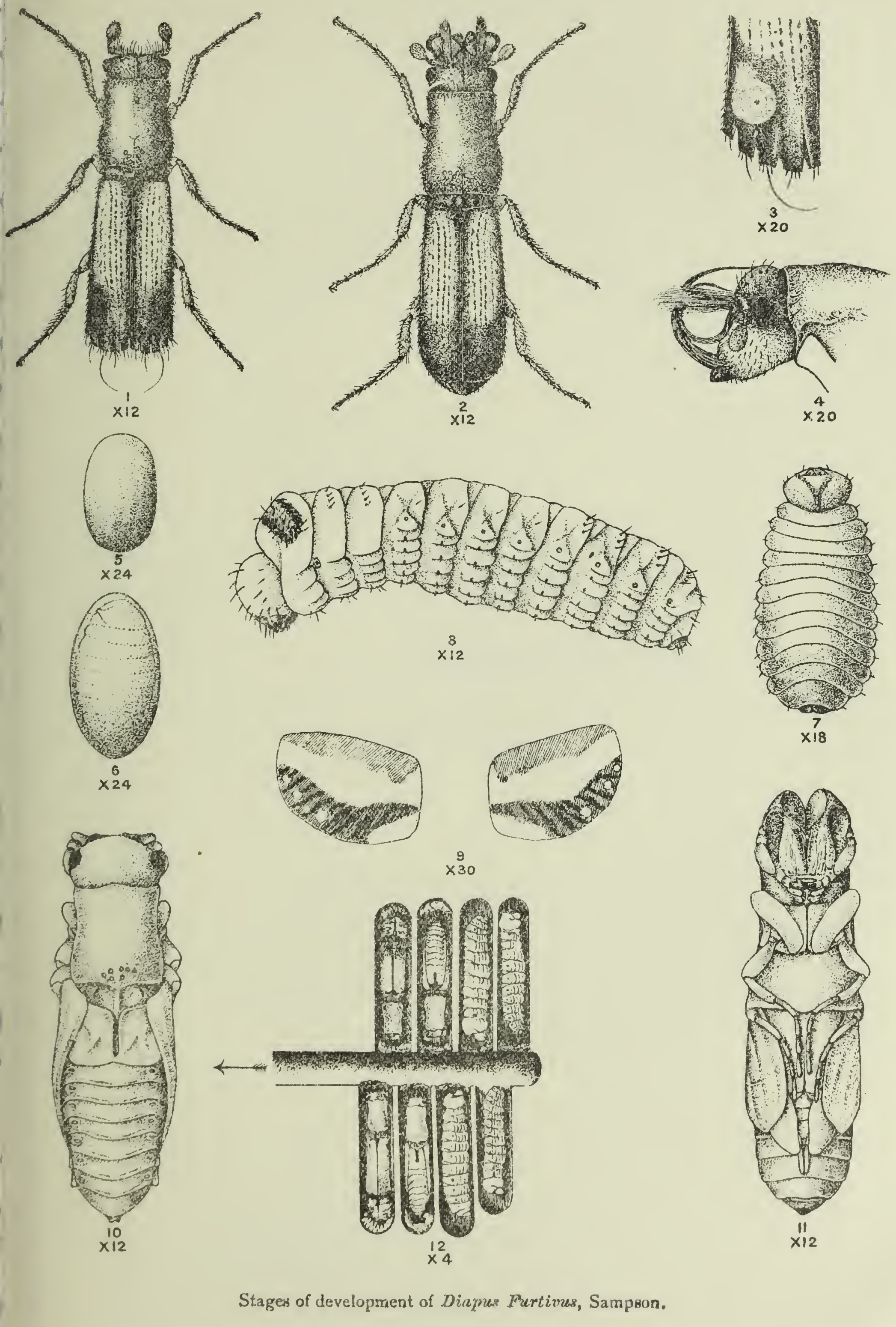
Description of Plate I.

Stages of development of *Diapus furtivus*, Sampson.

FIG. 1. *Diapus furtivus*, Sampson, ♂ beetle, × 12.
„ 2. „ „ „ ♀ beetle, × 12.
„ 3. Terminal portion of left elytron of ♂, showing wax scale, × 20.
„ 4. Lateral view of head of ♀, showing frontal brushes, × 20.
„ 5. Newly laid egg, × 24.
„ 6. Mature egg, × 24.
„ 7. Young larva, × 18.
„ 8. Mature larva, × 12.
„ 9. Prothoracic plates of mature larva, × 30.
„ 10. Dorsal view of ♂ pupa, × 12.
„ 11. Ventral view of ♀ pupa, × 12.
„ 12. Pupal cells showing stages of development, × 4.



Stages of development of *Diapus Furtivus*, Sampson.

Description of Plate II.

Gallery pattern of *Diapus furtivus*, Sampson, $\frac{4}{5}$ths natural size.

a, Wax-tube.
b, Entrance tunnel.
c, Main gallery.
d, Branch gallery.
e, Pupal chambers.
f, Stromatic growth of fungus.

J. B. Singh. del.

Gallery pattern of *Diapus furtivus*, Sampson.

INDIAN FOREST RECORDS.

Vol. VI.] 1917 [Part II

STATISTICS

Compiled in the Office of the Silviculturist, Forest Research Institute, Dehra Dun, during 1915-16.

INTRODUCTION.

THE compilation of statistics relating to the growth and outturn of Indian trees has been hampered in the past chiefly by lack of continuity and by absence of uniformity in the methods of measurement adopted. Mr. Troup's Note on the collection and tabulation of statistical *data* advanced proposals for a common system which might be applied over the whole of India. These proposals were considered by the Board of Forestry in 1913, and the methods and forms suggested were held to be generally suitable with such modifications as local conditions might demand. Volume measurements of forest crops were to be carried out by the Silviculturist or by special officers working in co-operation with him, but measurements of individual trees, of felled material, and of girth increments could be collected locally.

Some progress has been made in the adoption of a uniform system of measurements, but lack of continuity still accounts for the impossibility of utilizing much good work. Experience has indicated that this difficulty can be surmounted only by the appointment of special officers to establish, to supervise, and to maintain sample and experimental areas. This is the function of the Silviculturist, but even in 1913 the Board of Forestry recognized that the appointment of a special officer in each province was highly desirable owing to the urgent need of extending silvicultural research and to the impossibility of one officer controlling sample plots throughout India.

The figures in this publication have been compiled from the following sources :—

(I) Periodical girth-measurements of selected trees, recorded in registers by divisional forest officers ; the registers have been sent to the Silviculturist, the trees have been classified into girth-classes, the average increment for each girth-class calculated, and curves prepared for each sample area ; from the curves, the girth for each 10-year period

has been read off. The method is explained fully in Forest Bulletin No. 30. The girth-measurements have been carefully scrutinized and those which for any reason appeared to be unreliable have been omitted, so that the figures published may be held to represent fairly the rate of growth in the locality under existing conditions; their value as an average should be checked by a reference to the number of measurements upon which they are based, to the period for which the measurements have been maintained, as well as to the girth-class comprising the majority of the trees in the plot; where most of the trees are over 3 ft. in girth, figures for smaller trees are likely to show too slow a rate of growth, although measurements of trees which have suffered obviously from suppression have been rejected.

(II) Outturn registers of individual trees maintained by divisional officers. After classification into girth-classes, averages have been calculated for each coupe. The yield of each tree is entered in the register by a clerk on the spot as conversion is effected. Little supervision is possible, and the accuracy of the entries for any single tree or even for a whole coupe is open to question. But the averages for the different coupes check each other, and on the whole they yield an approximate estimate of the outturn under present conditions. The Yield Table for Deodar in Kulu Division has been prepared entirely by Mr. C. G. Trevor who has kindly given permission for its publication in this record.

(III) Sample plots established and maintained by the Silviculturist. The first plots were laid out in 1910-11 and their re-measurement was carried out in 1915-16. Fresh plots have been formed annually since 1910-11 and re-measurements are to be made at intervals of five years, so that every year certain plots will fall due. It is submitted that the results now published can be considered as only roughly approximate, but they will become more accurate with future quinquennial re-measurements. Figures for height-increment are not published because the measurements which have been taken are not numerous enough nor is the period over which measurements have been taken sufficiently prolonged as yet to yield reliable results. In course of time the average height measurements in the sample plots ought to give a fairly dependable height-increment.

(IV) Miscellaneous investigations by officers acting independently. Mr. C. G. Trevor's Yield Table for Deodar summarizes

the result of careful and patient investigation amongst the records of 20 years. It represents the labour of many months and makes public *data* of great value. For the first time the exact outturn of different sizes of Deodar is known. The statistics about Teak in Allapilli are based on most elaborate and laborious research work carried out in South Chanda under the control of Mr. J. Donald by Mr. Muhammad Ismail.

The object of publishing these statistics is to show the rate of growth and the outturn under present conditions. This is useful as indicating in some cases the need for alteration either of treatment or of species, while a basis is afforded to working-plans officers for framing estimates. But it is very necessary to bear in mind that in most cases the figures are incomplete, being based on comparatively few measurements, that they apply only to definite localities, and that with the exception of a few plots the trees have received practically no attention beyond protection. Any direct application of the statistics is therefore out of the question as yet. It is hoped that they may be suggestive, and that with the accumulation of further figures, which it is proposed to publish annually, a time will come when their practical application will be justifiable.

The effect of locality and of various methods of treatment upon the increment can be ascertained only by means of comparative statistics. Hitherto, published statements of results in India have been almost entirely wanting. It is perhaps one of the facts most striking to an unprejudiced critic that there are so few *data* available upon which to found an estimate of yield or to base a judgment on the existing system of management. This is not the place to elaborate the reasons for this state of affairs; but exception will hardly be taken if the utmost stress is laid here upon the urgency of extending statistical work in different provinces by the agency of local research officers working on similar lines. Until some knowledge has been acquired of the increment to be expected from the more important kinds of trees grown under different methods of treatment in varying localities, the thorough application of sound financial principles to forestry in India is not possible.

The Silviculturist wishes to acknowledge with grateful thanks the cordial co-operation and help of the following officers: Messrs. A. W. Blunt, F. Canning, J. Carr, M. W. Clifford, P. H. Clutterbuck, J. V. Collier, A. W. Dentith, J. Donald, P. J. Draper, A. N. Grieve, Lala Gulab Rai, H. H. Haines, C. M. Harlow, M. Hill, W. Jacob, R. Kirkpatrick, C. M. McCrie, Saiyid Mahdi Hasan, J. N. Oliphant, A. E. Osmaston, E. A. Smythies, C. G. Trevor, and R. S. Troup.

EDWARD MARSDEN,
Silviculturist.

September 1916.

SUMMARY OF RESULTS OF MEASUREMENTS

Siwalik Division (In the Dun),

Sample Plot.	Dholkot in Coupe VI.	Jamna Range.		Malhan Range.		Ramgarh Range.
Thinned or Unthinned.	Unthinned.	Unthinned.		Unthinned.		Unthinned.
Descriptive details.	Malhan Range, near Jhajra village, about 10 miles west of Dehra Dun, close to the Dehra Dun-Chakrata road.	Aspect northerly. Ground flat. Weak sandy loam with many stones. Well drained. Grassy. Height 70—75 ft. Density moderate. Fairly even-aged. ½ chain from the Timli-Sabhawala road, about the middle of the lower slopes of the Siwaliks.		Nearly flat. Aspect N.-E. At the base of the rougher slopes of the Siwaliks. Good sandy loam; upper 18″ nearly free from stones, and plenty of soil mixed with stones, lower down. Well-stocked, but open enough to allow saplings to grow vigorously. Height 85 ft.		Near Phandowala, below the Siwaliks, close to the Suswa. Aspect east and slightly north. Elevation 1,600 ft. Strong clayey loam, dry, free from boulders and *bajri*. Density good; the younger poles are too dense.
Period of measurement.	1906—1911	1892—1901	1901—1910	1892—1902	1902—1911	1889—1900
Total number of measurements.	248	88	86	100	94	66

RATE OF GROWTH

Age in years.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
10 . . .	...	...	...	...	...	...
20 . . .	...	1 1½	...	1 0	...	0 8½
30 . . .	0 5	1 7	0 8½	1 5	...	1 0½
40 . . .	0 7½	2 0½	1 0	1 9½	1 4	1 3
50 . . .	0 10½	2 5½	1 3	2 2	1 6½	1 5½
60 . . .	1 1	2 10	1 6½	2 7	1 9	1 8½
70 . . .	1 4	3 2½	1 10	3 0	1 11½	1 11½
80 . . .	1 7	3 6½	2 1½	3 5	2 2	2 3
90 . . .	1 10	3 10½	2 5	3 10	2 5	2 7
100 . . .	2 1	4 2½	2 8	4 3	2 8	2 11
110 . . .	2 3½	4 6½	2 11	4 8	2 11	3 3
120 . . .	2 6½	4 10½	3 2	5 1	3 3	3 8
130 . . .	2 9½	...	3 5½	5 5	3 7	4 1
140 . . .	3 0½	...	3 9	5 11½	3 11	4 6½
150 . . .	3 4	...	4 0½	...	4 3	5 0½
160 . . .	3 7½	...	4 4	...	4 7	5 7
170 . . .	3 11½	...	...	...	4 11	6 2
180 . . .	4 3½	...	...	...	5 3	...
190 . . .	4 8½	...	...	...	5 7	...
200 . . .	5 1½	...	...	...	5 11	...
210 . . .	5 6½	...	...	...	6 3	...
220 . . .	5 11½	...	...	...	6 7½	...
230 . . .	...	...	...	...	7 1	...

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

)IVISIONAL SAMPLE PLOTS. SPECIES—*SHOREA ROBUSTA.*

tern Circle, United Provinces.

SIDH (LACHIWALA RANGE).		THANO.	GANGES-TIRSAL RANGE GHAMANDPUR.		PLOTS COMBINED.	
Unthinned.		Unthinned.	Unthinned.		Unthinned.	
ct westerly. Slope 7°. ff clay loam with humus. ght of crop 75 ft. Well-cked but open enough to ourage saplings.		Aspect S. W. to W. S. W. Gradient 3°. A rather stiff loam with much *bajri* mixed in.	Elevation 1,500 ft. Gradient 4°. Aspect westerly. Good deep clayey loam. Density ·3. Height 25 to 70 ft. Growing vigorously when first measured. Crowns not spreading. Reproduction plentiful.		In the Dun.	
90—1900	1900—1910	1892—1901	1892—1901	1901—1910	...	
47	84	163	197	166	1,680*	

GIRTH.

Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Age in years.
...	...	...	...	...	...	10
0 11	...	...	0 10½	...	0 8	20
1 5	0 7½	0 7	1 3½	0 4	1 0	30
1 11	0 10	0 10½	1 10	0 6	1 4	40
2 4	1 0½	1 2	2 5	0 8	1 8	50
2 10	1 3	1 5½	3 1	0 10	1 11	60
3 4	1 5½	1 9	3 9	1 0½	2 2	70
3 10	1 8	2 1	...	1 3	2 6	80
4 4	1 11	2 5	...	1 5½	2 8	90
4 10	2 2½	2 10	...	1 8	3 2	100
...	2 5½	3 2	...	1 11	3 6	110
...	2 8½	3 6	...	2 3	3 10	120
...	2 11½	3 11	...	2 7	4 2	130
...	3 2	4 4	...	3 0	4 7	140
...	3 5½	4 9	...	3 5	5 0	150
...	3 9	5 2	...	3 10	5 4	160
..	4 0½	5 7	...	4 2	5 8	170
...	4 4	6 0	...	4 6	6 0	180
...	4 7½	6 5	...	4 10	6 4	190
...	4 10	6 10	...	5 2	6 9	200
...	...	...	...	...	...	210
...	...	...	...	...	...	220
...	...	...	...	...	...	230

* 0″ to 12″—167 measts.; 12″ to 24″—699 measts.; 24″ to 36″—495 measts.; 36″ to 48″—239 measts.; 48″ 0″—60 measts.; 60″ to 72″—15 measts.; 72″ to 84″—5 measts.; = 1,680 measurements.

Summary of results of Measurements in Divisional Sample Plots.

Species—*Shorea robusta*—contd.

Siwalik Division (Outside the Dun), Western Circle, United Provinces.

Sample Plot.	Dholkhand No. 1.	Dholkhand No. 2.	Dholkhand No. 3.	Lakarkote No. 1	Lakarkote No. 2.	Lakarkote No. 3.	Malowala 1st period.	Malowala 2nd period.	Plots combined.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned
Descriptive details.	On the south-western slopes of the Siwaliks between Hardwar and the Saharanpur-Dehra-Dun road.								Outside the Du[n]
Period of measurement.	1904-1911	1904-1911	1904-1911	1904-1911	1904-1911	1904-1911	1899-1905	1905-1911	
Total number of measurements.	149	88	41	257	45	18	130	132	860*

Rate of growth in girth.

Age in years.	Ft. in.	Ft. in.	Ft. in.	Ft. n.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
10	...	...	...	...	...	...	...	...	...
20	...	...	...	...	...	...	...	...	...
30	0 5½	0 5	0 5	0 4	0 4	0 3½	0 4½	0 4	0 4½
40	0 8½	0 7½	0 7½	0 6	0 5½	0 4½	0 6½	0 5½	0 6½
50	0 11½	0 10½	0 10½	0 8	0 7	0 6	0 8½	0 7½	0 8½
60	1 2½	1 1	1 1	0 10	0 8½	0 7½	0 10½	0 9½	0 10½
70	1 6	1 4	1 4	1 0	0 10	0 9½	1 0½	0 11½	1 0½
80	1 9½	1 6½	1 7	1 2	1 0	0 11	1 2½	1 1½	1 2½
90	2 1	1 9½	1 10	1 4	1 1½	1 0½	1 4½	1 3½	1 4½
100	2 4½	2 0½	2 1½	1 6	1 3½	1 2½	1 6½	1 5½	1 6½
110	2 8	2 3½	2 5	1 8	1 5	1 4	1 8½	1 7½	1 9
120	3 0	2 7	2 9	1 10	1 7	1 5½	1 10½	1 9½	2 0
130	3 4	2 11	3 1	2 0	1 8½	1 7½	2 0½	1 11½	2 3
140	3 8	3 3	3 5	2 2	1 10	1 9	2 2½	2 2	2 6
150	4 0	3 7	3 9½	2 4½	2 0	1 10½	2 5	2 5	2 9
160	..	4 0	...	2 7	2 2	2 0½	2 7½	2 8	3 0
170	...	...	...	2 10	2 4	2 2½	2 10	2 11½	3 3
180	...	...	...	3 1	2 6	2 4	3 0½	3 3	3 7
190	...	...	...	3 4	2 9	2 6½	3 4	3 6½	3 11
200	...	...	...	3 8	3 0	2 9	3 7½	3 11	4 3
210	...	...	...	4 0	3 3	3 0	3 11	4 4	4 8
220	...	...	...	...	...	...	...	4 9	5 1
230	...	...	...	...	...	...	...	...	5 6
240	...	...	...	...	...	...	...	...	6 0

Note.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—23 measts.; 12″ to 24″—427 measts.; 24″ to 36″—352 measts.; 36″ to 48″—43 measts.; 48′ to 60″—4 measts.; 60″ to 72″—4 measts.; 72″ to 84″—5 measts.; and 108″ to 120″—2 measts.; = 860 measurements.

[S]UMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.
SPECIES—*SHOREA ROBUSTA*—contd.

Siwalik Division, Western Circle, United Provinces.

[Sa]mple Plot.	No. 1.	No. 2.	No. 3.	No. 4.	Plots 2 to 4 Combined.
[T]hinned or [U]nthinned.	Thinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
[De]scriptive de[t]ails.	Elevation 1,900′ Lachiwala. Fairly even-aged, pure *Sal* pole forest. Probably fully stocked until great frost in beginning of 1905, which partly killed back many poles. These have recently been cut back, making the density not more than ·75. Flat land, edge of Tappar fertile clayey loam. Rainfall average 83″.	As for Sample Plot 1.	Elevation 1,500 ft. Rainfall about 80″. Flat locality. Fertile clayey loam. Young pole and sapling forest of *Sal, Sain* and *Sandan*; dense, fully stocked. *Sal* chiefly damaged by frost, but recovering.	Siwalik dry hill type of *Sal* forest, which probably never reaches large dimensions. Poor soil of gravel and pebbles. Hilly locality. Gradient 19° to 36°. Rainfall about 50°. There are a few bamboo clumps on the area.	
[Pe]riod of [m]easurements	1910-11 to 1915-16	1910-11 to 1915-16	1910-11 to 1915-16	1910-11 to 1915-16	1910-11 to 1915-16
[Tot]al number of [m]easurements.	96*	108	7	96	211†

RATE OF GROWTH IN GIRTH.

[A]ge in years.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
20	0 2½	0 1¼	1 3½	0 4	0 6½
30	0 5	0 3	1 11	0 7	0 11
40	0 8½	0 4¼	...	0 9½	1 3¼
50	0 11¾	0 6½	...	1 0¼	1 7½
60	1 3	0 9½	...	1 3	1 11¾
70	1 6½	1 1	...	1 5½	2 4
80	1 10	1 4	...	1 7¾	2 8½
90	2 1½	1 7½	...	1 10¼	...
100	2 5	1 11	...	...	...
110	2 8¾	2 3	...	...	...
120	3 0	2 6½	...	...	...
130	3 3	2 9½	...	...	...
140	3 6	...	...	...	...
150	3 9	...	...	...	...
160	3 11	...	...	...	...

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—5 measts.; 12″ to 24″—64 measts.; 24″ to 36″—26 measts; 36″ to 48″—1 meast ;=96 [mea]surements.

† 0″ to 12″—51 measts.; 12″ to 24″—136 measts.; 24″ to 36″—24 measts. =211 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.
SPECIES—*SHOREA ROBUSTA*—contd.

Pilibhit Division, Eastern Circle, United Provinces.

Sample Plot.	Chowk Gybi.		Comptt. XV, Neoria, W. C.		Comptt. VII, Banbasa, W. C.		Comptt. V, Banbasa, W. C.		Comptt. 20-V, Dhanarghat, W. C.		Kurrai Ghat, Mainakhot range.		Kalilur, Mainakhot range.		Gybi, Mainakhot range.		Mahofe, Mainakhot range.		
Thinned or Unthinned.	Unthinned.		Unthinned.		Unthinned.		Unthinned.		Unthinned.		Unthinned.		Unthinned.		Unthinned.		Unthinned.		Un thin
Period of measurement.	1898—1908		1910—1915		1910—1915		1911—1915		1898—1915		1884—1896		1881—1896		1881—1896		1884—1896		
Total number of measurements.	181		63		70		38		249		28		150		29		76		88
RATE OF GROWTH IN GIRTH.																			
Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.
20	0	6½	0	4	0	4	0	7	0	5½	0	7	1	0	1	2¾	0	11½	0
30	0	11	0	7¾	0	7¼	1	2¼	0	11¼	1	2	1	7	1	9¾	1	7½	1
40	1	3¼	0	11½	0	10¾	1	9¼	1	4¾	1	9½	2	4	2	4½	2	2½	1
50	1	7½	1	3¼	1	2	2	4	1	10½	2	5¼	2	8½	2	11¾	2	8½	2
60	1	11½	1	6½	1	5½	2	11	2	4	3	1	†3	0	3	5½	...		2
70	2	3½	1	9¾	1	9¼	3	5¼	2	10	...		...		4	0	...		2
80	2	7½	2	1	2	1½	3	11¼	3	4¼	...		...		...		...		3
90	2	11½	2	4	2	5¾	4	5¼	3	10½	...		...		...		...		3
100	3	3¼	2	7	2	10½	4	11	...		...		...		...		...		4
110	3	7	2	10	3	2¾	...		...		...		...		...		...		4
120	3	10¾	3	1½	3	7½	...		...		...		...		...		...		4
130	4	2	3	4¼	4	0	...		...		...		...		...		...		5
140	4	5¼	3	7½	4	5	...		...		...		...		...		...		5
150	4	8	3	10¾	4	10¼	...		...		...		...		...		...		6
160	4	10½	4	2¼	5	4	...		...		...		...		...		...		
170	...		4	5¾	5	10	...		...		...		...		...		...		
180	...		4	9¼	...		...		...		...		...		...		...		
190	...		5	0½	...		...		...		...		...		...		...		
200	...		5	3¼	...		...		...		...		...		...		...		

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—92 measts.; 12″ to 24″—456 measts.; 24″ to 36″—230 measts.; 36″ to 48″—75 measts.; 48″ to 60″ [illegible] measts.; 60″ to 72″—5 measts.; = 884 measurements.

† At 55 years of age.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA*—contd.

Pilibhit Division, Eastern Circle, United Provinces.

SAMPLE PLOT.	COMPTT. V. BANBASSA-CHUKA WORKING CIRCLE.	COMPTT. VII BANBASSA-CHUKA WORKING CIRCLE.	BOTH PLOTS COMBINED.
Thinned or Unthinned.	Thinned.	Thinned.	Thinned.
Period of measurement . . .	1911—1915	1910—1915	
Total number of measurements .	27	49	76*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.	Ft. in.	Ft. in.
20	0 9¼	0 6	0 8½
30	1 4½	0 11½	1 2½
40	2 0	1 4¼	1 8¼
50	2 7	1 9	2 2
60	3 2¼	2 2	2 8
70	3 9½	2 7¼	3 2¼
80	4 4	3 0½	3 8½
90	4 10½	3 5¼	4 2¼
100	5 4½	3 10	4 8½
110	5 10	4 3¼	5 2¾
120	...	4 9½	5 10
130	...	5 3½	...
140	...	5 10½	...

No *data* were available to calculate the age at 12″ girth. This was estimated.

*0″ to 12″—No. of measts., *nil*; 12″ to 24″—12 measts.; 24″ to 36″—16 measts.; 36″ to 48″—25 measts.; 48″ to 60″—18 measts.; 60″ to 72″—5 measts.; = 76 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA*—contd.

Pilibhit Division, Eastern Circle, United Provinces.

SAMPLE PLOT.	No. 1
Thinned or Unthinned.	Unthinned.
Descriptive details	*Sal* forest of rather poor qualit[y] but not the poorest type o[f] Pilibhit *Sal* forest. Densit[y] ·8, which is a good deal bett[er] than most of the Pilibh[it] forest. Undergrowth rath[er] scanty *Clerodendron*. Repr[o]duction not plentiful, consistin[g] of a few young *Sal*, *Mallotu[s]* and other spp. Soil—Sand[y] loam.
Period of measurement	1910-11 to 1915-16
Total number of measurements . . .	154*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.
40	0 8¼
50	1 0
60	1 3¾
70	1 7½
80	1 11¼
90	2 3½
100	2 8¼
110	3 2
120	3 8¼

NOTE.—Nothing has been added for the time required for the seedling to establish itself.
* 0" to 12"—4 measts. ; 12" to 24"—68 measts. ; 24" to 36"—72 measts. ; 36" to 48"—10 measts. ;=154 measurements.

[S]UMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.
SPECIES—*SHOREA ROBUSTA*—contd.
Haldwani Division, Western Circle, United Provinces.

SAMPLE PLOT.	No. 1.	No. 2.	No. 3.	No. 4.	No. 6.	No. 7.	No. 8.	Plots 1-4 and 6-8 combined.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
[D]escriptive details.*	Soil sandy loam with small boulders. Pure *Sal* of uniform type and good quality in large pole stage. Fully stocked but not crowded. No *Sal* reproduction and practically no undergrowth.	*Sal* forest of good quality, of plateau type, on undulating ground sloping to S. E. Fertile loam with small boulders. Dominant trees approaching full height-growth. No undergrowth.	Soil sandy loam. Uniform *Sal* forest of good quality in large pole stage. No *Sal* reproduction. Scanty undergrowth of *Clerodendron*, *Jaman Holarrhena*, etc. Flat land on low plateau.	Flat land, on low plateau. Soil sandy loam. Uniform *Sal* forest in the young pole stage. Scanty undergrowth of grass, which is becoming killed out.	*Sal* forest, of very fine quality on flat land; dominant trees have attained full height-growth. Density, ·7-Soil a fertile loam. Undergrowth of *Millettia auriculata* with some *Clerodendron*, *Mallotus*, etc.; no *Sal* reproduction.	Fairly good quality hill *Sal* in pole stage. Soil sandy loam with small boulders. No undergrowth and no *Sal* reproduction.	Soil fertile loam with boulders. *Sal* forest approaching full height-growth. Quality good. Scanty undergrowth of miscellaneous species. No *Sal* reproduction.	
[Per]iod of measurement.	1910-11 to 1915-16.	1910-11 to 1915-16	1910-11 to 1915-16	1910-11 to 1915-16	1910-11 to 1915-16	1910-11 to 1915-16	1910-11 to 1915-16	
[Tot]al number of measurements.	152	49	152	98	53	66	45	615*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
20	0	4	0	4½	0	3¾	0	6	0	4¾	0	6	0	4¼	0	4½
30	0	6	0	7½	0	6¼	0	10	0	8½	0	9¾	0	6¾	0	7¾
40	0	8	0	10½	0	8¾	1	2¼	1	0	1	1½	0	9½	0	11¼
50	0	10	1	1½	0	10¾	1	6¾	1	3¾	1	5	1	0	1	2¾
60	1	0¼	1	4½	1	1¼	1	11½	1	7¼	1	8¾	1	2¾	1	6½
70	1	2¼	1	7½	1	3½	2	4	1	11	2	0½	1	5¼	1	10¼
80	1	4¼	1	10½	1	6	2	8½	2	2½	2	5	1	7¾	2	2
90	1	6½	2	1½	1	8½	...		2	6½	2	10	1	10½	2	5¾
100	1	8½	2	4½	1	10¾	...		2	10¾	3	2¾	2	1¾	2	9¾
110	1	10¾	2	7¾	2	1¼	...		3	3¼	3	7½	2	5¼	3	2
120	2	1	2	11	2	4¼	...		3	8	...		2	9¼	3	6½
130	2	3½	3	2¼	2	7	...		4	1¼	...		3	1½	3	10¾
140	2	6¼	3	5½	2	9¾	...		4	8	...		3	6	4	3¼
150	2	9	3	8¾	3	0¾	...		5	3	...		3	10½	4	8
160	3	0¼	4	0	3	4	...		5	10½	...		4	2½	5	0½
170	3	3½	4	3¼	3	6¼	...		6	6	...		4	7	5	5
180	3	7¼	4	6¾	4	0¼	...		...		...		4	11	5	9¾
190	3	11¼	4	10	4	4¼	...		...		...		...		6	2¼
200	4	3¼	5	1½	4	8½	...		...		...		...		6	6½
210	4	7½	5	4¾	5	0½	...		...		...		...		6	11
220	5	0	5	8	5	4¾	...		...		...		...		...	
230	5	4½	5	11¼	5	8¾	...		...		...		...		...	
240	5	8¾	...		...		...		...		...		...		...	

[N]OTE.—Nothing has been added for the time required for the seedling to establish itself.

[*] 0″ to 12″—54 measts.; 12″ to 24″—162 measts.; 24″ to 36″—195 measts.; 36″ to 48″—139 measts.; 48″ to 60″—54 measts.; 60″ to 72″—10 [meast]s.; 72″ to 84″—1 meast.; = 616 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.
SPECIES—*SHOREA ROBUSTA*—contd.
Kheri Division (Trans-Sarda Forests), Eastern Circle, United Provinces.

Sample Plot.	West Sal Working Circle, Compt. 30.	West Sal Working Circle, Compt. 9 b.	West Sal Working Circle, Compt. 14 b.	East Sal Working Circle, Compt. 54.	East Sal Working Circle, Compt. 70.	Plots combine
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinn
Descriptive details .	Phanta Belt type. Area 2 acres: Pure *Sal* 70′ to 120′ in height in 1904.	Area 2 acres: High level ground.	Area 2 acres: Low level ground. *Sal* with a considerable mixture of *Terminalia tomentosa.*	Acrea 2 acres: Low level ground.	Area 2 acres: Low level ground.	•
Period of measurement	1904—1911	1905—1914	1905—1911	1905—1912	1905—1913	
Total number of measurements.	64	64	49	48	65	290

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	
30	0	10	1	3½	1	0	1	0	1	0	0	
40	1	2	1	11¼	1	5	1	5½	1	6	1	
50	1	6	2	6¾	1	9¾	1	11¼	2	0	1	
60	1	10½	3	2	2	2	2	4¾	2	5¼	2	
70	2	2¼	3	8¾	2	6½	2	10	2	10½	2	
80	2	6	4	3½	2	10¾	3	3	3	4¼	3	
90	2	9¾	4	10½	3	3	3	7¾	3	9½	3	
100	3	1½	5	7	3	7¼	4	0½	4	3½	4	
110	3	5½	...		3	11½	4	5	4	8¾	4	
120	3	9½	...		4	3¾	4	9¾	5	2¼	4	
130	4	1	...		4	8½	5	2½	5	7½	5	
140	4	5	...		5	2	5	7¼	...		5	
150	4	8¾	...		5	5	6	1	...		6	
160	5	0½	...		5	9	...		...		6	
170	5	4¼	...		6	0¾	...		...		7	
180	5	8	...		6	4	...		...		..	
190	6	0	...		6	6½	...		...		..	
200	6	3¾	...		6	9¼	...		...		..	
210	6	7½	...		7	0	...		...		..	
220	6	11	...				...		...		..	

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—Number of measurements, *nil*; 12″ to 24″—30 measts.; 24″ to 36″—74 measts.; 36″ to 48 measts.; 48″ to 60″—82 measts.; 60″ to 72″—20 measts.; 72″ to 84″—5 measts.; =290 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.
SPECIES—*SHOREA ROBUSTA*—contd.

Kheri Division (Cis-Sarda Forests), Eastern Circle, United Provinces.

Sample Plot.	Kishenpur Working Circle, Coupe IV.	Kishenpur Working Circle, Coupe VI.	Madha Working Circle, Coupe IV.	Madha Working Circle, Coupe VIII.	Katia Working Circle, Coupe V.	Gola Working Circle, Coupe IV.	Gola Working Circle Coupe VIII.	Mahorena Working Circle, Coupe IV	Plots combined.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details.	Area 1 acre: *Sal* with a few trees of miscellaneous species. "The plot is characterised by epicormic branches, no trees being free from them."	Area 2 acres: *Sal* with a good many trees of other species.	Area 1 acre: *Sal* with a fair mixture of *Terminalia tomentosa*.	Area 1 acre: pure *Sal*.	Area 1 acre: *Sal* with a few trees of other species.	Area 1 acre: *Sal* with a large admixture of other miscellaneous species.	Area 1 acre: *Sal* with an equal admixture of Sain (*Terminalia tomentosa*).	Area 1 acre: *Sal* with an equal mixture of *Terminalia tomentosa*.	...
Period of measurement.	1902—1911	1902—1911	1903—1914	1904—1914	1902—1918	1903—1912	1905—1912	1903—1911	...
Total number of measurements.	79	81	43	50	52	30	29	30	394*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
30	0	5	0	3	1	0	1	3¼	1	0	0	11½	1	0	0	11	0	8¼
40	0	7¾	0	6	1	5¾	1	10	1	5½	1	4¼	1	5½	1	4	1	1½
50	0	10½	0	9	1	11¼	2	4½	1	11	1	9	2	0½	1	9¼	1	6½
60	1	1	1	0	2	5	2	11¼	2	4½	2	2	2	7½	2	2	1	11½
70	1	3½	1	2	2	10½	3	4½	2	9½	2	7½	3	3	2	6½	2	4½
80	1	5½	1	4	3	4	3	9½	3	2¼	3	1	3	10	2	11	2	9½
90	1	7¾	1	6¼	3	9½	4	2	3	7¼	3	7¼	4	3½	3	3½	3	2½
100	1	10¼	1	8¼	4	2½	4	6	4	0	4	1½	4	8½	3	8¼	3	7
110	2	1	1	11	4	6¾	...		4	5	...		5	0	4	1	3	11½
120	2	3¾	2	1¼	4	10¾	...		4	9¾	...		...		4	5¾	4	4½
130	2	6¾	2	3¾	...		...		5	2¼	...		...		4	10	4	8½
140	2	10	2	6¼	...		...		5	9	...		...		5	1½	5	1
150	3	1	2	8¾	...		...		5	1½	...		...		5	4½	5	5
160	3	4	2	11½	...		...		...		...		...		5	7¼	5	9
170	3	7	3	2	...		...		...		...		...		5	9½	6	0
180	3	10¼	3	5	...		...		...		...		...		5	11¼	...	
190	4	1	3	7½	...		...		...		...		...		...		...	
200	4	4	3	10	...		...		...		...		...		...		...	
210	4	7	4	0¾	...		...		...		...		...		...		...	
220	4	10	4	3	...		...		...		...		...		...		...	
230	...		4	5½	...		...		...		...		...		...		...	
240	...		4	8	...		...		...		...		...		...		...	
250	...		4	10¼	...		...		...		...		...		...		...	
260	...		5	0¾	...		...		...		...		...		...		...	
270	.		5	3	...		...		...		...		...		...		...	
280	...		5	5	...		...		...		...		...		...		...	
290	...		5	7¼	...		...		...		...		...		...		...	
300	...		5	9½	...		...		—		...		...		...		...	
310	...		5	11¾	...		...		...		...		...		...		...	

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—Number of measurements, *nil*; 12″ to 24″—76 measts.; 24″ to 36″—163 measts.; 36″ to 48″—95 measts.; 48″ 60″—43 measts.; 60″ to 72″—17 measts.; =394 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.
SPECIES—*SHOREA ROBUSTA*—contd.

Gonda Division, Eastern Circle, United Provinces.

SAMPLE PLOT.	No. 4.	No. 4.	No. 6.	No. 8.	No. 8.	PLOTS COMBINED.
Thinned or Unthinned.	Thinned.	Thinned.	Thinned.	Thinned.	Thinned.	
Descriptive details .	*Sal* pole forest of good quality, fully stocked. Flat locality. Soil sandy loam. In 1911 the undergrowth consisted of a fair amount of thatching grass with some young *Sal* and miscellaneous species such as *Buchanania*, *Miliusa*, etc. Rainfall probably about 60 inches.		Undulating ground, rich sandy loam, moist situation. Fully stocked, even-aged *Sal* and *Sain* forest of excellent quality, approaching maturity which was heavily opened out by a regeneration felling in January 1911.	Flat, fairly moist locality, rich sandy loam. Even-aged *Sal* pole forest of very good quality, fully stocked, periodically thinned. Undergrowth of *Clerodendron*. A little *Sal* reproduction.		
Period of measurement.	1903-04 to 1910-11	1910-11 to 1915-16	1910-11 to 1915-16	1903-04 to 1910-11	1910-11 to 1915-16	1903-04 t[o] 1915-16
Total number of measurements.	63	69	67	119	90	408*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.
40	0	11½	1	0¼	1	6	0	11	0	6¾	0
50	1	3¼	1	3½	2	1	1	3	0	9¼	0
60	1	6¾	1	7	2	8½	1	7¼	1	0¼	1
70	1	10½	1	10½	3	4¾	1	11¾	1	3¼	1
80	2	2½	2	2	4	0¾	2	4¾	1	7	1
90	2	6½	2	5½	4	9½	2	10¾	1	10¾	2
100	2	11¼	2	9½	5	6¼	3	5	2	3	2
110	3	4	3	1½	...		3	11½	2	8	2
120	3	9	3	5¼	...		4	5¾	3	1½	3
130	...		3	9¼	.		5	0¼	3	7¼	3
140	...		...		...		5	6¾	4	1½	4
150	...		...		...		...		4	7½	5
160	...		...		...		..		5	1½	5
170	...		...		...		...		5	7½	...

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

*0″ to 12″—4 measts. ; 12″ to 24″—114 measts. ; 24″ to 36″—140 measts. ; 36″ to 48″—93 measts. ; 48[″ to] 60″—42 measts. ; 60″ to 72″—15 measts. ; = 408 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.
SPECIES—*SHOREA ROBUSTA*—contd.

Gonda Division, Eastern Circle, United Provinces—contd.

SAMPLE PLOT.	No. 3.	No. 3.	No. 5.	No. 7.	No. 7.	PLOTS COMBINED.
Thinned or Unthinned.	All Unthinned.					
Descriptive details .	*Sal* pole forest of good quality and fully stocked. Flat locality. Soil sandy loam. In 1911 the undergrowth consisted of a small quantity of thatching grass with some young *Sal*, and miscellaneous species such as *Buchanania*, *Miliusa*, etc. Rainfall probably about 60 inches.		Undulating ground, rich sandy loam: moist situation. Even-aged, fully stocked *Sal* forest with mixture of *Sain* of excellent quality, not subject to ordinary frost or drought.	Flat, fairly moist locality, rich sandy loam. Even-aged *Sal* pole forest of very good quality, fully stocked, unthinned. Under-growth of *Clerodendron*. A little *Sal* reproduction.		
Period of measurement.	1903-04 to 1910-11	1910-11 to 1915-16	1910-11 to 1915-16	1903-04 to 1910-11	1910-11 to 1915-16	1903-04 to 1915-16
Total number of measurements.	133	94	68	154	97	546*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
40	0	7½	0	9	0	7	0	6¼	0	4¼	0	4½
50	0	10¾	1	0	0	10½	0	8¾	0	6	0	6¾
60	1	2	1	3¼	1	2	0	11¼	0	8¼	0	8¾
70	1	5¼	1	6½	1	5¾	1	1¾	0	10¾	0	11¼
80	1	8½	1	10	1	9¼	1	4½	1	1¼	1	2¼
90	2	0	2	1½	2	1	1	6¾	1	3½	1	5¼
100	2	3¾	2	5¼	2	6	1	9¼	1	6¼	1	8¼
110	2	8	2	9	2	11	1	11¾	1	9¼	1	11½
120	3	0¼	3	0½	3	4½	2	3	2	0	2	2½
130	3	4¾	3	4	3	10¼	2	6¾	2	3¾	2	6
140	3	9	3	7¾	4	4¾	2	11	2	7¾	2	10½
150	...		3	11½	4	11½	3	3¾	3	0	3	3
160	...		...		5	6½	3	9½	3	4¾	3	8
170	...		...		...		4	3¾	3	9¾	4	1¼
180	...		...		...		4	9½	4	3¼	4	7¼
190	...		...		...		...		4	8¼	5	1¼
200	...		...		...		...		5	1	5	7¼
210	...		...		...		...		5	5¾	...	
220	...		...		...		...		5	10½	...	

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—2 measts.; 12″ to 24″—185 measts.; 24″ to 36″—197 measts.; 36″ to 48″—110 measts.; 48″ to 60″—40 measts.; 60″ to 72″—12 measts.;=546 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.
SPECIES—*SHOREA ROBUSTA*—contd.

Assam Province, Eastern Circle, Darrang Division.

Sample Plot.	Gorumara reserve.	Balipara reserve.	Plots combined.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details . . .	Ground level. Soil sandy loam with a layer of humus. Trees of fair growth; crop open.	Ground level. Soil sandy loam. Subsoil sandy. Crop complete over most of the area; in other parts scattered. Growth—average.	
Period of measurement . .	1908—1914	1908—1914	1908—1914
Total number of measurements.	143	237	380*

RATE OF GROWTH IN GIRTH.

Age in years.	Gorumara Ft.	Gorumara in.	Balipara Ft.	Balipara in.	Combined Ft.	Combined in.
20	0	3¼	0	4½	0	4
30	0	6¼	0	8	0	7½
40	0	9¼	0	11½	0	10½
50	1	0¾	1	3	1	2
60	1	4½	1	6½	1	5½
70	1	8	1	9½	1	9
80	1	11¾	2	1½	2	1
90	2	4	2	5¾	2	5
100	2	8½	2	10	2	9½
110	3	1	3	3	3	2
120	3	6	3	8	3	7
130	3	11	4	1	4	0
140	4	4½	4	6½	4	5½
150	4	10½	5	0	4	11½
160	5	5	...		5	5½
170	6	0	..		6	0½

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—17 measts.; 12″ to 24″—99 measts.; 24″ to 36″—102 measts.; 36″ to 48″—118 measts. 48″ to 60″—42 measts.; 60″ to 72″—2 measts.; =380 measurements.

Summary of results of measurements in Divisional Sample Plots.
Species—*Shorea robusta*—contd.
South Mandla Division, Northern Circle, Central Provinces.

ple Plot.	Kikra.	Hathidongar.	Majhgaon.	Pondharwani.	Gidhori.	Pakwar.	Plots combined.
hinned or nthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	
scriptive tails.	*Growing stock* of rather open density. Poor to medium quality. Height growth: good towards south-west and north-west, poor at north-east and south-east; good deal of mixed undergrowth; very little grass. Fair number of *Sal* seedlings; saplings and poles wanting. *Soil.*—South-west and north-west soil deep with no stones, red sandy with laterite and quartz. North-east and south-east very stony with much laterite. Trap at short distance. Flat locality.	On low ridge, with north-west aspect. Trap rock, laterite and some quartz. Soil dark and dull in colour, not black, fairly deep; mixed growth, 2′—4′ trees predominating, reproduction abundant but not promising. Trees not affected by frost or drought. Middle hill slopes.	Flat locality.	On low hill, aspect west. Rock-quartz and gneiss. *Soil.*—Sandy loam, with fair proportion of clay. *Growth.*—Open and patchy, saplings and pole stages present in fair number with some large trees in north-west corner, certain amount of admixture of other species, with some dwarf bamboo. Reproduction fairly satisfactory. Height-growth moderate. Middle hill slopes.	No descriptive details available. Poorer soil.	Density very open, strong grass, ground well drained. Several trees not vigorous. Better soil.	
od of easurement	1909—1915	1909—1915	1909—1915	1909—1915	1909—1915	1909—1915	
al number measurements.	72	71	147	277	187	41	795*

Rate of growth in girth.

ge in years.	Kikra Ft.	in.	Hathidongar Ft.	in.	Majhgaon Ft.	in.	Pondharwani Ft.	in.	Gidhori Ft.	in.	Pakwar Ft.	in.	Plots combined Ft.	in.
30	0	4½	0	10½	0	4¼	0	6	0	5½	0	8½	0	6½
40	0	7	1	3	0	7	0	9	0	8	1	1	0	8¾
50	0	9½	1	7	0	9¼	1	0	0	10¾	1	5½	1	0
60	0	11¼	1	10¾	0	11½	1	2½	1	1¼	1	10	1	2½
70	1	2	2	2½	1	1¾	1	5	1	3½	2	2¾	1	5
80	1	4	2	6	1	3½	1	8	1	5¾	2	7½	1	7½
90	1	6	2	9½	1	5½	1	10½	1	8	3	0	1	10
100	1	8	3	0¾	1	7¾	2	1	1	10½	3	4¾	2	0½
110	1	10	3	3½	1	9½	2	3¾	2	0¾	3	9½	2	3¼
120	2	0	3	6½	1	11½	2	6½	2	3	4	2¼	2	5¾
130	2	2	3	9	2	1½	2	9¼	2	5½	4	7	2	8½
140	2	3¾	3	11¾	2	3¾	3	0	2	7¾	5	0	2	11
150	2	5¾	4	1¾	2	5¾	3	2½	2	10¼	5	4¾	3	1½
160	2	7¾	4	4¾	2	8	3	5¼	3	0½	5	9½	3	4
170	2	9¾	4	7½	2	10	3	7¾	3	2¾	6	2	3	6½
180	2	11¾	4	10	3	0	3	10¼	3	5	6	6	3	9
190	3	1¾	5	0¼	3	2½	4	0¾	3	7¼	6	9	3	11¾
200	3	3¾	5	2½	3	5½	4	3¼	3	9¼	6	11¾	4	2¼
210	3	5½	...		3	8	4	5½	3	11½	7	2½	4	5
220	3	7¾	...		3	11	4	8	4	2	7	4¾	4	7¾
230	3	9¾	...		4	1¾	4	10½	4	4½	7	7½	4	10¼
240	4	0	...		4	1½	5	1	4	7	7	9½	5	1
250	4	1¾	...		4	7½	5	3½	4	9	8	0	5	3¾
260	4	3½	...		4	10½	5	6	4	11½	...		5	6¼
270	4	5¼	...			1½	5	8½	5	2	...		5	9
280	4	7	...			5¼	5	10¾	5	4½	...		5	11½
290	4	9	...		5	8¼	6	1	5	6¾	...		6	1¾
300	4	10¾	...		5	11½	6	3¼	5	9¼	...		6	4
310	5	0½	...		6	2	...		5	11¾	...		6	6½
320	5	2	...		6	4½	...		6	2	...		6	8½
330	5	3½	...		6	7	...		...		...		6	10¾
340	5	5	...		6	9¼	...		...		...		7	0¾
350	5	6½	...		6	11½	...		...		...		7	2¾
360	5	8	...		...		...		...		...		7	4¾
370	5	9½	...		...		...		...		...		7	6¾
380	5	10½	...		...		...		...		...		7	7½
390	6	0	...		...		..		...		...		7	10½
400	6	1¼	...		...		...		...		...		8	0¼

Note.—No data were available to show the time required to attain 12″ girth. This was estimated in each case.

* 0″ to 12″—Number of measurements—*nil*; 12″ to 24″—262 measts.; 24″ to 36″—291 measts.; 36″ to 48″—150 measts.; 48″ to 60″—6 asts.; 60″ to 72″—20 measts.; 72″ to 84″—7 measts.; 84″ to 96″—4 measts.; 96″ to 108″—1 meast.; =795 measurements.

:EMENTS IN DIVISIONAL SAMPL

OBUSTA—contd.

Circle, Central Provinces.

No. 10a, Dhire.	No. 10b, Dhire.	N4b, Atar-haha.	Muki.	Kareli.	Plots Combined.	Sample Plot.
Unthinned.	Unthinned.	thinned.	Unthinned.	Unthinned.	Unthinned.	Thinned or Unthinned.
Deep sandy loam and loamy sand. Dead leaves, very litt'e grass, exposed to frost. Middle-aged pole forest, good straight growth but the crowns are all suffering from frost-bite.	Exposed to frost and drought. Fresh sandy loose loam, deep. Very little grass, a few ferns, *Sal* seedlings dead leaves. Excellent height-growth, tall straight boles.	Exd to frost. Slayey. Re- a of badly Je forked and n ing trees. ti t-growth g onsiderable, de mostly to ht stems. a br to	Soil, loamy and compact for 2′ thin quartz stones and laterite for 6′. Below this deep micaceous sand, fairly loose. Probably not well-aerated Flat, well-drained.	Slightly sloping grown with N. aspect. Soil sandy and stony quartz. Poor *Sal* forest with other species mixed *Terminalia tomentosa* and *Buchanania latifolia*.		Descriptive details.
1907 to 1916	1907 to 1916	to 1916	1913 to 1916	1910 to 1916		Period of measts.
199	141	51	81	72	1,815*	Total No. of measts.

IN GIRTH.

Ft. in.	Ft. in.	in.	Ft. in.	Ft. in.	Ft. in.	Age in years.
...	...	...	...	...	...	10
...	...	...	...	...	...	20
...	0 5½	1	...	...	...	30
0 2¾	0 8½	2½	0 4¼	0 0¾	...	40
0 4½	0 11½	4	0 6½	0 2	0 5	50
0 6½	1 2½	5¾	0 9	0 3¾	0 6½	60
0 8¼	1 5½	7½	0 11½	0 5½	0 8	70
0 10	1 8½	9¼	1 2	0 6¾	0 9½	80
0 11½	1 11½	10¾	1 4¼	0 8½	0 11	90
1 1¼	2 2½	0½	1 6¾	0 10	1 1	100
1 3	2 5½	2¼	1 9¼	0 11¾	1 3¼	110
1 5	2 8½	4	1 11¾	1 1¼	1 5¼	120
1 7	2 11¾	6	2 3	1 3	1 7	130
1 9	3 2½	8	2 6½	1 4½	1 9	140
1 11	3 5½	10¼	2 10	1 6	1 11	150
2 1	3 8½	¼	3 1½	1 7¾	2 1	160
2 3	3 11¾	2½	3 5	1 9¼	2 3¼	170
2 5	4 2	4¼	3 8½	1 11	2 5¾	180
2 7	4 4¾	7	4 0	2 1	2 8	190
2 9	4 7½	9½	4 5	2 3	2 10½	200
2 11¼	4 10¼	0	4 9½	2 5¼	3 1	210
3 1½	5 1	2½	5 2	2 7½	3 3¼	220
3 3½	5 4	5	5 6¼	2 9¾	3 5¾	230
3 5½	...	7½	...	3 0¼	3 8	240
3 7¾	...	10	...	3 3	3 10½	250
3 10¼	...	...	...	...	4 1	260
4 1¼	...	...	...	...	4 3½	270
4 4	...	...	...	...	4 5¾	280
4 6¾	...	...	...	...	4 8¼	290
4 9½	...	...	...	...	4 10¾	300
5 0½	...	...	...	...	5 1	310
5 3	...	...	...	...	5 3½	320
5 5¾	...	...	...	...	5 5½	330
5 7½	...	...	...	...	5 7½	340
5 11¼	...	...	...	...	5 9¼	350
...	...	...	...	...	5 11¼	360
...	...	...	...	...	6 1¼	370
...	...	...	...	...	6 3½	380
...	...	...	...	...	6 5¼	390
	...		...	...	6 7	400

to 72″—46 measts. ; 72″ to 84″—23 measts. ; 8

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SUMMARY OF RESULTS OF GIRTH MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.
SPECIES—*SHOREA ROBUSTA*—contd.

Balaghat Division, Southern Circle, Central Provinces.

Sample Plot.	No. 1, Kukra.	No. 2, Barmhera.	No. 3, Bhondabawan.	No. 4, Nayagarh.	No. 5, Bhengiapahar.	No. 9, Jabatola.	No. 7a, Topla.	No. 7b, Topla.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details.	Soil partly heavy clay, partly admixture of sand. Subsoil gravel and stones. Severe damage by frost. Good height-growth, but many trees dead or dying. Soil covered with grass. *Sal* regeneration.	Level ground, severely frost-bitten. Soil in parts sandy but mostly heavy clay. Subsoil clay. Soil covering grass.	Liable to being frost-bitten. Sandy loam varying in depth, in part clay with a little sand. Leaves, ferns, a little grass and *Sal* undergrowth.	No frost. Soil.—Loam and clay with stony subsoil, excellent growth, long boles. Young *Sal* undergrowth, ferns and a little grass.	S., E. & N. Slopes, in parts very steep. Very exposed to frost. Very poor soil. Small stunted trees mostly.	Much exposed to frost. Fresh clayey loam. On the whole good straight boles. *Sal* undergrowth and ferns and leaves.	Secure from frost. Soil clayey. *Sal* regeneration and ferns. Heavy thinnings removal of all dead, dying and suppressed trees.	No damage by frost. Soil clayey. Subsoil stoney. Only moderately good. Straight growth, but no great height. Soil covering grass, shrubs and ferns.
Period of measts.	1898 to 1915	1888 to 1916	1888 to 1915	1888 to 1916	1898 to 1915	1898 to 1915	1907 to 1916	1907 to 1916
Total No. of measts.	37	93	45	51	42	45	18	109

Sample Plot.	No. 7c, Topla.	No. 8a, Lalbarra.	No. 8b, Lalbarra.	No. 9, Topla.	No. 10a, Dhire.	No. 10b, Dhire.	No. 11a, Dhire.	No. 11b, Dhire.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details.	Deep fresh clay soil, a few ferns, thorns and young seedlings and leaves; not exposed to frost.	Not exposed to frost. Moorum soil very stony. Comparatively poor growth especially in height but straight.	Not exposed to frost. Soil covering shrubs and ferns very poor owing to bad soil.	Exposed to frost. Better trees in groups where soil is deeper. At top a thin layer of clay on rocky subsoil. *Sal* regeneration, thorns, grass, ferns.	Deep sandy loam and loamy sand. Dead leaves, very little grass, exposed to frost. Middle-aged pole forest, good straight growth but the crowns are all suffering from frost-bite.	Exposed to frost and drought. Fresh sandy loose loam, deep. Very little grass, a few ferns, *Sal* seedlings dead leaves. Excellent height-growth, tall straight boles.	Exposed to frost. Stony quartzite and mica. Dead leaves, ferns and no regeneration. Height-growth not considerable, tendency to grow crooked and develop branches owing to the low density.	Exposed to frost but not considerably. Soil very stony, the surface is strewn with undecomposed pieces of quartz. Plenty of regeneration, a few ferns, leaves, thorns and climbers.
Period of measts.	1907 to 1916	1907 to 1916	1907 to 1915	1907 to 1916	1907 to 1916	1907 to 1916	1907 to 1916	1907 to 1916
Total No. of measts.	135	26	33	81	109	141	42	40

Sample Plot.	No. 12a and 12b, Kelakachhar.	No. 13a, Atarchaha.	No. 13b, Atarchaha.	No. 14a, Atarchaha.	No. 14b, Atarchaha.	Muki.	Kareli.	Plots Combined.	Sample Plot.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Thinned or Unthinned.
Descriptive details.	Exposed to frost, rock quartz. Very stony. Strewn with quartz fragments. Stunted growth, tendency to develop large spreading crowns. Regeneration poor to moderate.	Sandy loam and small stones. Good growth, straight, tall stems. Very little grass and seedlings of *Sal* and other species.	No frost; clayey, becoming sandy at one foot depth. Very little grass and seedlings of *Sal* and other species; good growth straight tall stems.	Gentle slope. N. Aspect. Soil clayey. Leaves and often ferns. Height-growth not considerable but mostly straight stems often with epicormic branches owing to frost. Exposed to frost.	Exposed to frost. Soil clayey. Removal of badly grown forked and spreading trees. Height-growth not considerable, but mostly straight stems.	Soil, loamy and compact for 2' thin quartz stones and laterite for 6'. Below this deep siliceous sand, fairly loose. Probably not well-aerated Flat, well-drained.	Slightly sloping ground with N. aspect. Soil sandy and stony quartz. Poor *Sal* forest with other species mixed *Terminalia tomentosa* and *Buchanania latifolia*.		Descriptive details.
Period of measts.	1907 to 1916	1907 to 1916	1907 to 1919	1907 to 1919	1907 to 1916	1913 to 1916	1910 to 1919		Period of measts.
Total No. of measts.	35	188	145	60	51	81	72	1,815*	Total No. of measts.

RATE OF GROWTH IN GIRTH.

Age in years.	No. 1 Ft. In.	No. 2 Ft. In.	No. 3 Ft. In.	No. 4 Ft. In.	No. 5 Ft. In.	No. 9 (Jabatola) Ft. In.	No. 7a Ft. In.	No. 7b Ft. In.
10	...	...	...	...	...	...	...	...
20	...	...	...	...	...	...	...	...
30	...	...	...	...	...	...	...	...
40	0 4	0 1½	0 2½	9 2½	0 7½	0 6½	0 8½	0 6½
50	0 6	0 2¾	0 4¼	0 4¼	0 9½	0 9	1 0	0 8½
60	0 8	0 4	0 7¼	0 7½	0 11½	0 11½	1 3	0 11
70	0 10½	0 6¼	0 9¾	0 10½	1 2	1 2	1 6¼	1 1½
80	1 1	0 7	1 0	1 1	1 4½	1 4¾	1 9½	1 3½
90	1 3¼	0 8½	1 2½	1 4	1 6½	1 9¼	2 1	1 5½
100	1 5½	0 10	1 4¾	1 6¾	1 9	1 8½	2 4½	1 7½
110	1 8	0 11¼	1 7¼	1 9¾	1 11½	1 11	2 8½	1 9½
120	1 10½	1 0½	1 9½	2 0	2 2¼	2 1½	3 1	1 11½
130	2 1	1 2	2 0	2 3	2 5	2 3½	3 5¾	2 1¼
140	2 3½	1 3½	2 2½	2 6	2 8	2 5¾	3 11	2 4
150	2 6¼	1 4¾	2 5½	2 8½	2 11	2 8	4 4½	2 6½
160	2 8½	1 6½	2 7¾	2 11¾	3 2½	2 10½	4 9½	2 8½
170	2 10¾	1 7¾	2 10½	3 2½	3 5½	3 0¾	...	2 10½
180	2 11¾	1 9	3 0½	3 5½	3 9	3 3	...	3 0¾
190	3 1½	1 10½	3 3½	3 7¾	4 0½	3 5½	...	3 3
200	3 3	2 0	3 6	3 10½	4 3¼	3 7½	...	3 5
210	3 4¾	2 1½	3 8½	4 0¾	4 7½	3 10	...	3 7½
220	3 6¼	2 3½	3 11	4 3	4 11	4 0	...	3 9½
230	3 8	2 5	4 1	4 5	...	4 2½	...	3 11½
240	3 9½	2 9½	4 4	4 7	...	4 4½	...	4 1½
250	3 11½	2 8½	4 0¾	4 0	...	4 6½	...	4 4½
260	4 0¾	2 10	4 8	4 11½	...	4 8½	...	4 6½
270	4 2¼	2 11½	4 10¾	5 1½	...	4 10	...	4 9
280	4 4½	3 2	5 0½	5 3¾	...	5 0	...	4 11½
290	4 9	3 4½	5 2½	5 5½	...	...	...	5 2½
300	4 8½	3 6½	5 5	5 7½	...	...	...	5 5½
310	4 10½	3 8½	5 7½	5 9¾	...	...	...	5 8
320	5 1	3 11	5 10	5 11½	...	...	...	5 11½
330	5 3½	4 1½	6 0½	6 1½	...	...	...	...
340	5 5¼	4 3¼	6 2¾	6 3½	...	...	...	...
350	5 7¼	4 6	6 5½	6 5¾	...	...	...	...
360	5 9½	4 8½	6 7¾	6 7½	...	...	...	...
370	5 11¾	4 10½	6 10½	6 9¾	...	...	...	...
380	6 1½	5 0½	7 0½	6 11½	...	...	...	...
390	6 3¼	5 3	7 4	7 1½	...	...	...	...
400	6 5½	5 5¾	7 7	7 3½	...	...	...	...

Age in years.	No. 7c Ft. In.	No. 8a Ft. In.	No. 8b Ft. In.	No. 9 (Topla) Ft. In.	No. 10a Ft. In.	No. 10b Ft. In.	No. 11a Ft. In.	No. 11b Ft. In.
10	...	...	...	...	...	...	...	...
20	...	...	...	...	...	...	...	...
30	...	...	...	...	...	0 5½	...	...
40	9 5¼	0 0¾	0 10½	0 10½	0 2¼	0 8½	9 9½	9 10½
50	0 8¼	1 1	1 2	1 2½	0 4½	0 11½	9 11½	1 1½
60	0 11	1 4	1 5½	1 5½	0 6½	1 2½	1 1½	1 4½
70	1 1½	1 7	1 8½	1 8½	0 8½	1 5½	1 4	1 7½
80	1 4½	1 10½	1 11½	1 11½	0 10	1 8½	1 6½	1 10¾
90	1 7½	2 1	2 2½	2 2½	0 11½	1 11½	1 8½	2 2
100	1 10	2 4	2 5½	2 5½	1 1½	2 2½	1 19¾	2 5½
110	2 1	2 6½	2 8	2 8	1 3	2 5½	2 1	2 8½
120	2 4	2 9½	2 11	2 11	1 5	2 8½	2 3	2 11½
130	2 7	3 0½	3 2	3 1½	1 7	2 11½	2 5½	3 2½
140	2 10½	3 3	3 4½	3 4½	1 9	3 2½	2 7½	3 5½
150	3 2	3 5½	3 7½	3 7½	1 11	3 5½	2 9¾	3 8½
160	3 5½	3 8½	...	3 10½	2 1	3 8½	3 0	3 11½
170	3 9	3 10½	...	4 1½	2 3	3 11½	3 3	...
180	4 0½	4 1½	...	4 4½	2 5	4 2	3 6	...
190	4 3½	4 4	...	4 7½	2 7	4 4½	3 9	...
200	4 5½	4 6½	...	4 10½	2 9	4 7½	3 11½	...
210	4 8½	4 8½	...	5 1½	2 11½	4 10½	4 2½	...
220	4 10½	4 11	...	5 4	3 1½	5 1	4 5½	...
230	5 0½	...	...	...	3 3½	5 4	4 8	...
240	5 2½	...	...	...	3 5½	...	4 19½	...
250	5 3½	...	...	...	3 7½	...	...	...
260	5 5½	...	...	...	3 10½	...	...	...
270	5 7	...	...	...	4 1½	...	...	...
280	5 8½	...	...	...	4 4	...	...	...
290	5 10	...	...	...	4 6½	...	...	...
300	5 11½	...	...	...	4 9½	...	...	...
310	6 0½	...	...	...	5 9½	...	...	...
320	6 1½	...	...	...	5 3	...	...	...
330	6 2½	...	...	...	5 5¾	...	...	...
340	6 3½	...	...	...	5 7½	...	...	...
350	6 4½	...	...	...	5 11½	...	...	...
360	6 5½	...	...	...	...	...	...	...
370	6 7	...	...	...	...	...	...	...
380	9 8½	...	...	...	...	...	...	...
390	6 9½	...	...	...	...	...	...	...
400	6 10½	...	...	...	...	...	...	...

Age in years.	No. 12a and 12b Ft. In.	No. 13a Ft. In.	No. 13b Ft. In.	No. 14a Ft. In.	No. 14b Ft. In.	Muki Ft. In.	Kareli Ft. In.	Plots Combined Ft. In.	Age in years.
10	...	...	...	...	...	...	...	...	10
20	...	...	0 1	...	...	...	...	...	20
30	...	...	0 2	0 1½	0 1	...	...	...	30
40	0 4½	0 1½	9 3½	9 3½	0 2½	0 4½	0 9½	...	40
50	0 6¾	9 2½	0 4½	0 5½	0 4	0 6½	0 2	0 5	50
60	0 9	0 4	0 5½	0 7½	9 5½	9 9	0 3½	0 6½	60
70	0 11½	0 5½	0 6½	0 9	0 7½	0 11½	9 5½	0 8	70
80	1 1½	0 7	0 7½	0 11½	0 9½	1 2	0 6½	0 9½	80
90	1 4	0 8½	0 8½	1 1	0 10½	1 4½	0 8½	9 11	90
100	1 6¾	0 10	0 19	1 3	1 0½	1 6½	0 10	1 1	100
110	1 9½	0 11½	0 11½	1 5	1 2½	1 9½	0 11½	1 3½	110
120	2 0½	1 0¾	1 0¾	1 7	1 4	1 11½	1 1½	1 5½	120
130	2 3½	1 2	1 2½	1 9	1 6	2 3	1 3	1 7	130
140	2 6½	1 3½	1 3½	1 11	1 8	2 6½	1 4½	1 9	140
150	2 9½	1 5	1 5½	2 1½	1 10½	2 10	1 9	1 11	150
160	3 0½	1 6½	1 7	2 2½	2 ½	3 1½	1 7½	2 1	160
170	3 3	1 7½	1 8½	2 6½	2 2½	3 5	1 9½	2 3½	170
180	3 6	1 9½	1 10½	2 8½	2 1½	3 8½	1 11	2 5½	180
190	3 9	1 10¾	2 0½	2 11	2 7	4 0	2 1	2 8	190
200	3 11½	2 0	2 2	3 1½	2 9½	4 5	2 3	2 10½	200
210	...	2 1½	2 4	3 4	3 9	4 9½	2 5½	3 1	210
220	...	2 3½	2 6	3 6½	3 2½	5 2	2 7½	3 3½	220
230	...	2 4½	2 8	3 9	3 5	5 6½	2 9½	3 5½	230
240	...	2 6½	2 10	3 11	3 7½	...	3 9½	3 8	240
250	...	2 8	3 0	...	3 10	...	3 3	3 10½	250
260	...	...	3 2½	...	...	...	...	4 1	260
270	...	...	3 4½	...	...	...	...	4 3½	270
280	...	...	3 6½	...	...	...	...	4 5½	280
290	...	...	3 9	...	...	...	...	4 8½	290
300	...	...	3 11½	...	...	...	...	4 10½	300
310	...	...	4 1½	...	...	...	...	5 1	310
320	...	...	4 3½	...	...	...	...	5 3½	320
330	...	...	4 5½	...	...	...	...	5 5½	330
340	...	...	5 9½	...	...	...	...	5 7½	340
350	...	...	5 3	...	...	...	...	5 9½	350
360	...	...	5 5	...	...	...	...	5 11½	360
370	...	...	5 7½	...	...	...	...	6 1½	370
380	...	...	5 9½	...	...	...	...	6 3½	380
390	...	...	5 11½	...	...	...	...	6 5½	390
400	...	...	9 2½	...	...	...	...	6 7	400

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 9" to 12"—26 measts.; 12" to 24"—739 measts.; 24" to 36"—581 measts.; 36" to 48"—281 measts.; 48" to 60"—104 measts.; 60" to 72"—46 measts.; 72" to 84"—23 measts.; 84" to 96"—6 measts.; 96" to 108"—6 measts.; 108" to 120"—3 measts.; =1,815 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA*—contd.

Singhbhum Division, Province of Bihar and Orissa.

SAMPLE PLOT.	AKSHOY SHILA.	SAMTA-HENDA KULI OLD ROAD.	TALSADA.	CHITI-NITI.	THALKA-BAD.	HENDA-KULI.	TIRIL-POSI.	NOS. 1 TO 7 PLOTS COMBINED.	CHITI-NITI.
Thinned or Unthinned.	Un-thinned.	Unthinned.	Un-thinned.	Un-thinned.	Un-thinned.	Un-thinned.	Un-thinned.	Unthinned.	Thinned.
	1	2	3	4	5	6	7		
Period of measurement.	1889—1914	1887—1914	1910—1914	1908—1912	1910—1914	1906—1910	1910—1914		1908—1912
Total number of measurements.	68	192	51	40	67	32	37	*486	†52

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
30	0 6	0 6	0 6	0 5¼	0 6½	1 0½	1 1½	0 5¼	0 8
40	0 9	0 9	0 9½	0 8	0 9¾	1 6	1 7	0 8½	0 11½
50	1 0	1 0½	1 0½	0 11	1 1	1 10½	2 0½	1 0	1 3½
60	1 3½	1 3½	1 4	1 2	1 4	2 3	2 6	1 3½	1 7
70	1 7½	1 7½	1 7½	1 5	1 7	2 6½	2 11	1 7	1 10½
80	1 11	1 11½	1 11	1 8½	1 10	2 10	3 3	1 11	2 2½
90	2 3	2 3½	2 2¾	2 0	2 1½	3 1	3 6½	2 3	2 7
100	2 7	2 7¾	2 6½	2 3½	2 4¾	3 3½	3 10	2 7	2 11½
110	2 11¼	3 0¼	2 10½	2 7¼	2 8	3 6	4 1½	2 11	...
120	3 4	3 5½	3 3	2 11	2 11¼	3 8½	4 6	3 3	...
130	3 9¼	3 11½	3 8¼	...	3 2½	3 10¾	4 10½	3 7	...
140	4 2½	4 5½	4 1½	...	3 6	4 1	5 2½	3 11	...
150	4 7½	4 11	4 7	...	3 9½	4 3¼	5 7	4 3½	...
160	5 0	5 3½	5 1	...	4 1½	4 5½	5 11½	4 8	...
170	5 4	5 7	5 6	...	4 5¼	4 7½	...	5 0½	...
180	5 8	5 11	5 11	...	4 9	4 9½	...	5 5	...
190	5 11½	6 3	..	...	5 1	4 11	...	5 9½	...
200	6 3	6 7½	...	...	5 5½	...	...	6 2½	...
210	...	7 0	...	...	5 10½	...	...	6 7½	...
220	...	7 4½	...	...	...	...	...	7 1	...
230	...	7 9	...	...	...	...	...	7 6	...
240	...	8 1	...	...	.	...	...	7 11½	...
250	...	8 4	...	...	...	...	...	8 3½	...
260	...	8 7	...	...	...	...	...	8 7	...
270	...	8 10	...	...	...	...	...	8 10½	...
280	...	...	...	...	...	...	...	9 0	...

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0" to 12"—3 measts.; 12" to 23"—28 measts.; 24" to 36"—54 measts.; 36" to 48"—117 measts.; 48" to 60"—141 measts.; 60" to 72"—99 measts.; 72" to 84"—22 measts.; 84" to 96"—15 measts.; 96" to 108"—7 measts.; = 486 measurements.

† 0" to 12"—Number of measurements, *nil*; 12" to 24"—37 measts.; 24" to 36"—15 measts.; = 52 measurements.

Record of Periodical Volume Measurements.

Siwalik Division, Western Circle, United Provinces.

Number of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½' from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.						
						Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	Periodic Yields.				Total to date.		
									Number of stems.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. f.	c. ft.
			Trees 10"	and over	in girth										
1	1910-11	*Shorea robusta* . .	522	19·2	47	160	2,055	2,215	...	...	72	72(*a*)	...	72	72
			Trees 6"	—10" in	girth										
			43	8·4	14	...	12	12	...	...	...	...	...	...	...
		Total .	565	18·4	44	160	2,067	2,227							
			Trees 10"	and over	in girth										
	1915-16	*Shorea robusta* . .	461	21·8	50	386	1,832	2,218	61	33	251	284	33	323	356
			Trees 6"	—10" in	girth										
			52	8·5	14	...	11	11	...	...	...	...	...	...	...
		Total .	513	20·8	...	386	1,843	2,229							
			Trees 10"	girth an	d over										
2	1910-11	*Shorea robusta* . .	569	19	47	258	2,107	2,365	...	...	...	...	...	...	...‡
			Trees 6"	—10" in	girth										
			39	7·2	13	...	8	8	...	...	...	...	...	...	...
		Total .	608	18·3	45	258	2,115	2,373							
			Trees 10"	girth an	d over										
	1915-16	*Shorea robusta* . .	565	21·6	52	498	2,320	2,818	...	...	...	...	...	...	...
			Trees 6"	—10" in	girth										
			43	8·7	14	...	10	10	...	...	...	...	...	...	...
		Total .	608	21·0	...	498	2,330	2,828							

(*a*) Poles from cut back frost-damaged stems.
‡ Unthinned.

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*contd.*

Siwalik Division, Western Circle, United Provinces—concld.

Number of Sample Plot.	Year of measurement.	SPECIES.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	TOTAL.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	TOTAL.	TOTAL TO DATE. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
			Trees 4″	girth an	d over										
3	1910-11	*Shorea robusta*	1,333	7·6	23	...	418·7	418·7	...	...	...	...	...	...	...
		Terminalia tomentosa	298	6·3	20	...	50·6	50·6	...	...	...	...	...	...	...
		Ougeinia dalbergioides	509	5·7	19	...	34·0	34·0	...	...	...	...	...	...	...
		Total	2,140	7·0	22	...	503·3	503·3							
	1915-16	*Shorea robusta*	719	10·9	30	...	555	555							
		Terminalia tomentosa	158	9·9	34	...	112	112	772*	...	164	164	...	164	164
		Ougeinia dalbergioides	526	7·3	25	...	122	122							
		Total	1,403	9·6	30	...	789	789							
			Trees of	10″girth	and over	only									
4	1910-11	*Shorea robusta*	272	13·3	33	...	423	423	...	...	...	...	...	...	...
		Buchanania latifolia	40	12·6	24	...	37	37	...	...	...	...	...	...	...
		Others	58	13·9	30	...	72	72							
		Total	370	13·2	32	...	532	532							
	1915-16	*Shorea robusta*	307	14·2	35	...	392	392							
		Buchanania latifolia	44	13·9	28	...	53	53	12	...	9·7	9·7	...	9·7	9·7
		Others	60	14·5	26	...	86	86							
		Total	411	14·2	33	...	531	531							

* 772 stems per acre removed in thinning on 31st January 1916; average girth 7·0.

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*contd.*

Haldwani Division, Western Circle, United Provinces.

Number of Sample Plot.	Year of measurement.	SPECIES.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.						
									Periodic Yields.				Total to date.		
						Timber over 24″ in girth.	Small wood 6″—24″ in girth.	TOTAL.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	TOTAL.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
			18″ girth and over.												
1	1910-11	*Shorea robusta* . . .	197	31·9	83	2,242	1,051	3,293	...	...	...	...	...	...	...
			12″—18″ girth.												
			43												
		Total .	240												
			18″ girth and over.												
	1915-16	*Shorea robusta* . . .	183	33·7	75	1,917	1,203	3,120	15	85	101	186	85	101	186
			12″ to 18″ girth.												
			35												
		Total .	218												
			18″ girth and over.												
2	1910-11	*Shorea robusta* . . .	285	33·4	73	3,289	1,662	4,951	...	...	...	...	...	...	...
			12″—18″ girth.												
			95												
		Total .	380												
			18″ girth and over.												
	1915-16	*Shorea robusta* . . .	148	42·7	83	3,222	920	4,142	230	497	820	1,317	497	820	1,317
			18″ girth and over.												
3	1910-11	*Shorea robusta* . . .	303												
			10″—18″ girth.												
			77												
		Total .	380	28·2	59	2,268	2,182	4,450	...	...	...	...	...	...	...

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*contd.*

Haldwani Division, Western Circle, United Provinces—contd.

Number of Sample Plot.	Year of measurement.	SPECIES.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET.			INTERMEDIATE YIELDS PER ACRE FROM THINNINGS.						
									PERIODIC YIELDS.				TOTAL TO DATE.		
						Timber over 24″ in girth.	Small wood 6″—24″ in girth.	TOTAL.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	TOTAL.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
			18″ girth and over.												
	1915-16	*Shorea robusta* . . .	263	...		2,394	2,054	4,448	30	107	171	278	107	171	278
			10″ to 18″												
			54	...		...	123	123							
		Total .	317	29·4	68	2,394	2,177	4,571							
			18″ girth and over.												
4	1910-11	*Shorea robusta* . . .	548												
			6″—9″ girth												
			530												
			Under 6″												
			509	(All suppressed)											
		Total .	1,587	10·8	31	...	1,008	1,008	...	...	...	...	...	...	...
			6″ and over.												
	1915-16	*Shorea robusta* . . .	1,104	11·9	37	...	1,204	1,204	83	...	135	135	...	...	...
			24″ girth and over.												
6	1910-11	*Shorea robusta* . . .	118	44·3	91	3,475	957	4,332	...	...	...	...	...	...	...
			18″—24″ girth.												
			21												
		Total .	139												
			24″ girth and over.												
	1915-16	*Shorea robusta* . . .	101	46·1	97	3,115	805	3,920	23	385	116	501	385	116	501
			18″ to 24″ girth.												
			26												
		Total .	127												

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*contd.*

Pilibhit Division, Eastern Circle, United Provinces.

Number of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½' from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.						
									Periodic Yields.				Totlto date.		
						Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	Number of stems.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.
				(inches.)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. f
1	1910-11	*Shorea robusta* . . .	537	17·8	33	445	1,149	1,594	...	...	...	...	...	...	...
		Others	137	13·4	22	...	186	186	...	...	...	...	...	...	...
		TOTAL .	674	...	...	445	1,335	1,780	...	...	...	...	...	...	...
	1915-16	*Shorea robusta* . . .	358	23·1	38	551	1,155	1,706	61	...	158	158	...	158	158
		Others	68	17·2	26	...	130	130	...	...	...	...	...	...	...
		TOTAL .	426	...	...	551	1,285	1,836	...	...	...	...	...	...	...

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*contd.*

Gonda Division, Eastern Circle, United Provinces.

Number of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet. Timber over 24″ in girth.	Volume per acre in solid cubic feet. Small wood 6″-24″ in girth.	Volume per acre in solid cubic feet. Total.	Intermediate yields per acre from thinnings. Periodic Yields. Number of stems.	Periodic Yields. Timber over 24″ in girth.	Periodic Yields. Small wood 6″-24″ in girth.	Periodic Yields. Total.	Total to date. Timber over 24″ in girth.	Total to date. Small wood 6″-24″ in girth.	Total to date. Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
			12″ girth	and over											
3	1903-04	*Shorea robusta* . . .	326	21·5	51	436	1,079	1,515	...	...	...	...	...	...	...
			12″ girth	and over											
		Others	22	17·2	36	...	59	59	...	...	...	...	...	...	...
		Total .	346	...	...	436	1,138	1,574	...	...	...	...	...	...	...
			10″ girth	and over											
	1910-11	*Shorea robusta* . . .	358	22·5*	52*	657	1,269	1,926	...	...	...	...	...	...	...
			6″—10″	girth											
			86												
		Total .	444												
			10″ girth	and over											
		Others	34	18·9	44	...	106	106	...	...	...	...	...	...	...
			6″—10″	girth											
			32												
		Total .	66												
		Grand Total .	510			657	1,375	2,032	...	...	...	...	...	...	...
			10″ girth	and over											
	1915-16	*Shorea robusta* . . .	368	22·7	53	906	1,412	2,318							
			10″ girth	and over					32	...	126	126	...	126	126
		Others	34	22·8	57	...	194	194							
		Total .	402			906	1,606	2,512	...	...	...	...	...	...	...

* Girth and height increments appear small because several small trees which have grown to be 10″ in girth have been included in measurements of 1910-11.

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*contd.*

Gonda Division, Eastern Circle, United Provinces—contd.

Number of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet. Timber over 24″ in girth.	Small wood 6″-24″ in girth.	Total.	Intermediate yields per acre from thinnings. Periodic Yields. Number of stems.	Timber over 24″ in girth.	Small wood 6″-24″ in girth.	Total.	Total to date. Timber over 24″ in girth.	Small wood 6″-24″ in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
			12″ girth and over												
4	1903-04	*Shorea robusta* . . .	174	23·8	54	621	592	1,213	...	...	...	...	...	...	...
			12″ girth and over												
		Others	46	23·0	48	97	228	325	...	...	...	...	...	...	...
		Total .	220			718	820	1,538	...	...	...	...	...	...	...
			10″ girth and over							Dominant and dominated					
	1910-11	*Shorea robusta* . . .	176	24·0†	56†	827	593	1,420	...	12	19	31	...	...	...
			6″—10″ girth							Suppressed and dead					
			24			...	...	...	...	2	36	38	...	...	...
		Total .	200			...	...	...	...	14	55	69	14	55	69
			10″ girth and over							Dominant and dominated					
		Others	40	22·6†	45†	...	154	154	...	20	80	100			
			6″—10″ girth							Suppressed and dead					
			20			...	...	...	...	50	14	64	...	...	...
		Total .	60			...	...	...	...	70	94	164	70	94	164
		Grand Total .	260			827	747	1,574	...	84	149	233	84	149	233
			10″ girth and over												
	1915-16	*Shorea robusta* . . .	186	26·2	57	1,102	744	1,846	} 12	...	82	82	84	231	315
			10″ girth and over												
		Others	38	22·1	57	...	204	204							
		Total .	224			1,102	948	2,050	...	...	...	...	...	...	...

† Girth and height increment appears small because several small trees which have grown to be 10″ in girth have been included in measurements of 1910-11.

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*contd.*

Gonda Division, Eastern Circle, United Provinces—contd.

Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.						
								Periodic yields.				Total to date.		
					Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.
			(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
		24″ girth	and over											
1910-11	*Shorea robusta* . . .	98	43·0	73	1,962	489	2,451	...	...	...	...	...	...	...
		24″ girth	and over											
	Terminalia tomentosa . .	32	37·2	70	415	256	671	...	...	...	...	...	...	...
	Total .	130			2,377	745	3,122							
		24″ girth	and over											
1915-16	*Shorea robusta* . . .	100	46·6	81	2,508	1,094	3,602	...	...	...	...	...	...	...
		24″ girth	and over											
	Terminalia tomentosa .	31	41·2	62	562	301	863	...	...	...	...	...	...	...
	Total .	131			3,070	1,395	4,465							
		24″ girth	and over						*Shorea robusta*					
1910-11	*Shorea robusta* . . .	68	42·2	72	1,514	363	1,877	23	269	119	388	269	119	388
									Other species					
								43	767	239	1,006	767	239	1,006
								66	1,036	358	1,394	1,036	358	1,394
		24″ girth	and over											
1915-16	*Shorea robusta* . . .	62	50·4	86	2,007	779	2,786	4	83	not recorded	83	1,119	358	1,477
		24″ girth	and over											
	Others . . .	2	36	71	4	24	28	...	...	...	...	...	...	...
	Total .	64			2,011	803	2,814							

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*concld.*

Gonda Division, Eastern Circle, United Provinces—concld.

No. of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet: Timber over 24″ in girth.	Volume per acre in solid cubic feet: Small wood 6″—24″ in girth.	Volume per acre in solid cubic feet: Total.	Intermediate yields per a[cre] from thinnings. Periodic yields: Number of stems.	Periodic yields: Timber over 24″ in girth.	Periodic yields: Small wood 6″—24″ in girth.	Periodic yields: Total.	Total to [date]: Timber over 24″ in girth.	Total to [date]: Small wood 6″—24″ in girth.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
			12″ girth	and over										
7	1903-04	*Shorea robusta* . . .	202	27·5	65	1,622	1,051	2,673	...	...	...	...	...	...
			12″ girth	and over										
		Others	53	23·3	58	298	161	459	...	...	...	...	...	...
		Total .	255			1,920	1,212	3,132						
			12″ girth	and over										
	1910-11	*Shorea robusta* . . .	212	28·5†	65†	1,811	1,073	2,884	...	...	...	...	...	...
			12″ girth	and over										
		Others	58	24·0†	58†	343	183	526	...	...	...	...	...	...
		Total .	270			2,154	1,256	3,410						
			12″ girth	and over										
	1915-16	*Shorea robusta* . . .	126	38·2	77	1,869	2,336	4,205	83	72	137	209	72	137
			12″ girth	and over										
		Others	17	36·9	71	38	213	251	44	...	128	128	...	128
		Total .	143			1,907	2,549	4,456	127	72	265	337	72	265
			12″ girth	and over										
8	1903-04	*Shorea robusta* . . .	125	31·4	68	1,353	727	2,080	...	...	...	...	...	...
			12″ girth	and over										
		Others	11	24·4	60	18	55	73	...	...	...	...	...	...
		Total .	136			1,371	782	2,153						
			12″ girth	and over										
	1910-11	*Shorea robusta* . . .	134	34·1	70	1,800	805	2,605	not recorded	35	24	59	35	24
			12″ girth	and over										
		Others	11	19·6‡	41‡	...	47	47	...	...	...	...	...	...
		Total .	145			1,800	852	2,652						
			12″ girth	and over										
	1915-16	*Shorea robusta* . . .	122	35·7	68	1,731	2,185	3,916	} 21	137	140	277	172	164
			12″ girth	and over										
		Others	24	19·4	45	...	73	73						
		Total .	146			1,731	2,258	3,989						

† Girth and height increment appears small because several small trees which have grown to be 12″ in girth have been incl[uded in the] measurements of 1910-11.

‡ Girths and heights smaller than in 1903-04, because 13 small trees which have grown to be 12″ in girth have been included in [the measure]ments of 1910-11 and 5 of the large trees have been removed in the thinnings.

SPECIES—*SHOREA ROBUSTA.*

n South Mandla Division, Central Provinces, Motinala Range, Phen Working Circle, the following outturn was obtained from Sal trees in different coupes:—

Girth.	Number of trees con-verted.	SLEEPERS. Narrow gauge 5′ by 7″ × 4″.	SLEEPERS. Metre gauge 6′ by 8″ × 4½″.	SLEEPERS. Broad guage 10′ by 10″ × 5″.	SCANT-LINGS. 10″ × 5″ 10½ feet to 16 feet long.	VOLUME (CUBIC FEET). Sleepers.	VOLUME (CUBIC FEET). Scant-lings.	Total.	Average per tree (cubic feet con-verted).
			Green trees.						
upe IV Over 6′	824	4,042	9,157	1,377	1,727	22,207	7,614	29,821	36·2
upe V Over 6′	593	2,867	6,799	162	680	13,520	3,142	16,662	28·1
upe VI Over 6′	548	2,300	6,209	365	2,333	12,754	10,230	22,984	41·9
upe IV 5′ to 6′	430	1,417	3,403	327	498	7,561	2,224	9,785	22·7
upe V 5′ to 6′	591	2,543	4,702	144	385	10,000	1,844	11,844	20·0
upe VI 5′ to 6′	349	903	1,601	146	703	3,761	3,074	6,835	19·6
upe IV 4½′ to 5′	223	951	1,570	100	199	3,610	882	4,492	20·1
upe V 4½′ to 5′	226	750	1,267	15	73	2,679	345	3,024	13·4
upe VI 4½′ to 5′	320	604	1,207	84	392	2,675	1,714	4,389	13·7
			Dead trees.						
upe IV Over 6′	25	71	249	27	24	620	104	724	28·9
upe V Over 6′	51	208	410	32	57	923	258	1,181	23·1
upe VI Over 6′	74	241	468	45	311	1,085	1,334	2,419	32·7
upe IV 5′ to 6′	121	272	770	88	97	1,710	427	2,137	17·6
upe V 5′ to 6′	85	174	554	26	75	1,086	345	1,431	16·8
upe VI 5′ to 6′	90	157	359	31	137	793	605	1,398	15·5
upe IV 4½′ to 5′	78	280	560	33	18	1,121	74	1,195	15·3
upe V 4½′ to 5′	95	270	446	15	32	981	153	1,134	11·9
upe VI 4½′ to 5′	184	280	602	38	165	1,300	761	2,061	11·2

SPECIES—*SHOREA ROBUSTA.*

utturn from Coupe VII, Compartment 21, Baihar Range, Balaghat Division, Central Provinces.

Girth.	Number of trees con-verted.	NUMBER OF SLEEPERS. Broad Gauge.	NUMBER OF SLEEPERS. Narrow Gauge.	NUMBER OF Scant-lings.	VOLUME (CUBIC FEET). Sleepers.	VOLUME (CUBIC FEET). Scant-lings.	VOLUME (CUBIC FEET). Total.	Average per tree (cubic feet con-verted).
to 3′ 11″	249	7	1,174	17	1,164	16	1,180	4·7
to 4′ 11″	535	271	3,628	30	4,421	27	4,448	8·3
to 5′ 11″	328	429	3,085	80	4,414	16	4,430	13·5
to 6′ 11″	118	288	1,665	34	2,569	15	2,584	21·9
to 7′ 11″	109	429	1,870	180	3,233	47	3,280	30·1
to 8′ 11″	47	185	1,073	10	1,653	4	1,657	35·3
to 9′ 11″	31	143	964	191	1,409	45	1,454	46·9
to 10′ 11″	17	86	620	55	887	19	906	53·3
to 11′ 11″	7	43	263	45	320	7	327	46·7
to 12′ 11″	8	54	456	86	621	12	633	79·1
to 13′ 11″	2	...	175	...	170	...	170	85·0
to 14′ 11″	3	56	247	13	425	7	432	144·0

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe No. VIII, Compartment 22, Baihar Range, Balaghat Division, Centr Provinces.

Girth.	Number of trees converted.	NUMBER OF Sleepers. Broad Gauge.	NUMBER OF Sleepers. Narrow Gauge.	NUMBER OF Scantlings.	VOLUME (CUBIC FEET). Sleepers.	VOLUME (CUBIC FEET). Scantlings.	VOLUME (CUBIC FEET). Total.	Averag per tr (cubi feet co verte
3′ to 3′ 11″	74	8	202	122	222·7	133·5	356	4
4′ to 4′ 11″	330	166	1,509	650	2014·6	711·0	2,726	8
5′ to 5′ 11″	273	410	1,744	630	3048·0	689·1	3,737	13
6′ to 6′ 11″	135	299	1,310	309	2259·9	338·0	2,598	19
7′ to 7′ 11″	80	229	997	172	1724·7	188·1	1,913	23
8′ to 8′ 11″	41	151	565	225	1047·4	246·2	1,294	31
9′ to 9′ 11″	23	71	368	43	592·0	47·1	639	28
10′ to 10′ 11″	9	19	266	25	320·2	27·4	348	38
11′ to 11′ 11″	3	37	33	5	154·1	5·5	160	53
12′ to 12′ 11″	4	4	34	10	46·2	10·9	57	14

SPECIES—*SHOREA ROBUSTA.*

Outturn from Compartment No. 23, Coupe IX of Baihar Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF Sleepers. Broad Gauge.	NUMBER OF Sleepers. Narrow Gauge.	NUMBER OF Scantlings.	VOLUME (CUBIC FEET). Sleepers.	VOLUME (CUBIC FEET). Scantlings.	VOLUME (CUBIC FEET). Total.	Average per tree (cubic feet converted).
3′ to 3′ 11″	138	61	—	724	201·2	791·9	993	7·2
4′ to 4′ 11″	408	210	—	2,757	692·7	3,015·5	3,708	9·3
5′ to 5′ 11″	272	429	—	2,092	1,415·1	2,288·1	3,703	14·6
6′ to 6′ 11″	190	386	—	1,910	1,273·3	2,089·1	3,362	17·7
7′ to 7′ 11″	97	294	—	1,310	969·9	1,432·8	2,403	24·8
8′ to 8′ 11″	43	135	—	683	445·3	747·1	1,192	27·8
9′ to 9′ 11″	35	146	—	631	481·6	690·2	1,172	33·5
10′ to 10′ 11″	20	73	—	570	240·8	623·4	864	43·2
11′ to 11′ 11″	4	18	—	122	58·4	133·5	192	48·0
12′ to 12′ 11″	2	10	—	43	33·0	47·1	80	40·0
13′ to 13′ 11″	3	13	—	128	42·9	140·1	183	61·0
14′ to 14′ 11″	1	10	—	36	33·0	39·4	72	72·0
16′ to 16′ 11″	1	15	—	72	49·5	78·7	128	128·0

SPECIES—*SHOREA ROBUSTA.*

Outturn from Compartment 30, Coupe 19, Baihar Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF			VOLUME (CUBIC FEET).			Average per tree (cubic feet converted).
		Sleepers.		Scantlings.	Sleepers.	Scantlings.	Total.	
		Broad Gauge.	Narrow Gauge.					
3′ to 3′ 11″	159	16	...	691	52·8	756·5	809	5·1
4′ to 4′ 11″	199	105	...	1,168	346·4	1,282·0	1,628	8·2
5′ to 5′ 11″	141	339	...	1,154	1,118·2	1,281·3	2,400	17·0
6′ to 6′ 11″	88	309	5	871	1,024·2	955·6	1,980	20·7
7′ to 7′ 11″	40	170	...	633	560·8	704·1	1,265	31·6
8′ to 8′ 11″	14	60	...	355	197·9	298·3	496	35·4
9′ to 9′ 11″	11	50	...	239	164·9	261·5	426	38·7
10′ to 10′ 11″	3	17	...	50	56·1	54·7	111	37·0

SPECIES—*SHOREA ROBUSTA.*

Outturn from Compartment 62, Coupe No. VI, Baihar Range, Balaghat Division, Central Provinces.

Girth.	Number of tree converted.	NUMBER OF			VOLUME (CUBIC FEET).			Average per tree (cubic feet converted).
		Sleepers.		Scantlings.	Sleepers.	Scantlings.	Total.	
		Broad Gauge.	Narrow Gauge.					
I Class. 6 feet girth and over.	88	472	840	...	2,374	...	2,374	27·0
II Class. 5 feet to 5 feet 11 inches.	237	664	1,440	...	3,590	..	3,590	15·1
III Class. 4 feet to 4 feet 11 inches.	411	382	2,004	...	3,208	...	3,208	7·8
IV Class. 3 feet to 3 feet 11 inches.	267	60	1,066	...	1,234	...	1,234	4·6

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe No. 6, Compartment 61, Baihar Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF Sleepers. Broad Gauge.	NUMBER OF Sleepers. Metre Gauge.	NUMBER OF Sleepers. Narrow Gauge.	NUMBER OF Scantlings.	VOLUME (CUBIC FEET). Sleepers.	VOLUME (CUBIC FEET). Scantlings.	VOLUME (CUBIC FEET). Total.	Average per tree (cubic feet converted).
I Class. 6 feet girth and over.	148	637	1,894	94	...	5,034	...	5,034	34·0
II Class. 5 feet to 5 feet 11 inches.	277	700	1,918	94	...	5,277	...	5,277	19·2
III Class. 4 feet to 4 feet 11 inches.	303	320	2,201	58	...	4,415	...	4,415	14·6
IV Class. 3 feet to 3 feet 11 inches.	215	61	926	19	...	1,609	...	1,609	7·5

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe No. 3, Compartment 30, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF SLEEPERS. Broad Gauge.	NUMBER OF SLEEPERS. Narrow Gauge.	Total Volume (c.ft.) of sleepers *	Average per tree (cubic feet converted).
4′ to 4′ 11″	9	2	68	72·7	8·1
5′ to 5′ 11″	27	32	268	366·0	13·6
6′ to 6′ 11″	20	30	272	363·4	18·2
7′ to 7′ 11″	12	41	321	447·3	37·3
8′ to 8′ 11″	5	14	144	186·2	37·2
9′ to 9′ 11″	3	11	29	64·5	21·5

* No scantlings.

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe No. 4, Compartment 34, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF		VOLUME (CUBIC FEET).			Average per tree (cubic feet converted).
		SLEEPERS. Narrow Gauge.	Scantlings.	Sleepers.	Scantlings.	Total.	
3′ to 3′ 11″ . .	15	39	13	37·9	21·0	59	4·0
4′ to 4′ 11″ . .	159	1,023	196	994·6	304·0	1,299	8·2
5′ to 5′ 11″ . .	147	1,680	190	1,633·3	293·7	1,927	13·1
6′ to 6′ 11″ . .	100	1,689	119	1,642·0	205·6	1,848	18·5
7′ to 7′ 11″ . .	40	808	74	785·6	122·4	908	22·7
8′ to 8′ 11″ . .	11	261	9	253·7	15·5	269	24·5
9′ to 9′ 11″ . .	6	124	4	120·5	6·8	127	21·1
10′ to 10′ 11″ . .	3	184	6	179·2	10·4	190	63·3

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe No. 4, Compartment 35, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF SLEEPERS.*			Total Volume (c. ft.) of Sleepers.	Average per tree (cubic feet converted).
		Broad Gauge.	Metre Gauge.	Narrow Gauge.		
3′ to 3′ 11″ .	24	4	18	115	152	6·3
4′ to 4′ 11″ .	106	34	86	751	971	9·2
5′ to 5′ 11″	169	201	196	1,620	2,532	15·0
6′ to 6′ 11″ .	138	288	112	1,624	2,697	19·5
7′ to 7′ 11″ .	70	137	80	1,108	1,649	23·6
8′ to 8′ 11″ .	28	76	14	540	797	28·5
9′ to 9′ 11″ .	22	83	4	456	723	32·8
10′ to 10′ 11″ .	6	45	2	223	368	61·3
11′ to 11′ 11″ .	1	...	1	45	45	45·0
12′ to 12′ 11″ .	5	16	3	92	147	29·4
13′ to 13′ 11″ .	1	...	...	86	84	84·0

* No scantlings.

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe No. I, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF SLEEPERS. Broad Gauge.	NUMBER OF SLEEPERS. Narrow Gauge.	Total Volume (c. ft.) of sleepers.*	Average per tree (cubic feet converted).
4′ to 4′ 11″	182	274	1,788	2,643	14·5
5′ to 5′ 11″	150	267	1,644	2,479	16·5
6′ to 6′ 11″	465	1,602	6,797	11,893	25·6
7′ to 7′ 11″	252	1,445	5,213	9,835	39·0
8′ to 8′ 11″	93	697	3,078	5,292	56·9
9′ to 9′ 11″	27	163	1,130	1,633	60·5
10′ to 10′ 11″	14	152	741	1,222	69·3
11′ to 11′ 11″	3	45	130	275	91·7

* No scantlings.

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe No. II, Compartment 58, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF SLEEPERS. Broad Gauge.	NUMBER OF SLEEPERS. Metre Gauge.	Total Volume (c. ft.) of sleepers.*	Average per tree (cubic feet converted).
4′ to 4′ 11″	32	32	379	474	14·8
5′ to 5′ 11″	36	10	656	671	18·6
6′ to 6′ 11″	193	474	3,650	5,112	26·5
7′ to 7′ 11″	57	216	1,619	2,287	31·9
8′ to 8′ 11″	18	41	704	820	45·5
9′ to 9′ 11″	12	63	483	678	56·5
10′ to 10′ 11″	4	...	296	288	72·0

* No scantlings.

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe No. 5, Compartment 23, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	Number of sleepers.		Total Volume (c.ft.) of sleepers. *	Average per tree (cubic feet converted).
		Broad Gauge.	Narrow Gauge.		
I Class. 6 feet girth and over .	345	1,390	5,765	10,190	29·5
II Class. 5 feet to 5 feet 11 in. .	262	485	2,815	4,337	16·6
III Class. 4 feet to 4 feet 11 in. .	238	204	1,786	2,410	10·1
IV Class. 3 feet to 3 feet 11 in. .	72	5	470	473	6·6

* No scantlings.

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe No. 5, Compartment 35, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	Number of sleepers.		Total Volume (cubic feet) of sleepers.†	Average per tree (cubic feet converted).
		Broad Gauge.	Narrow Gauge.		
I Class. 6 ft. girth and over .	91	380	1,231	2,499	27·5
II Class. 5 ft. to 5 ft. 11 in. .	92	196	731	1,357	14·8
III Class. 4 ft. to 4 ft. 11 in. .	72	98	370	683	9·5
IV Class. 3 ft. to 3 ft. 11 in. .	14	18	69	126	9·0

† No scantlings.

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe 4, Compartment 37, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	Number of sleepers.			Total Volume (cubic feet) of sleepers.‡	Average per tree (cubic feet converted).
		Broad Gauge.	Metre Gauge.	Narrow Gauge.		
I Class. 6 ft. girth and over . . .	138	523	444	1,178	3,536	25·6
II Class. 5 ft. to 5 ft. 11 in. . . .	331	778	821	1,479	5,238	15·8
III Class. 4 ft. to 4 ft. 11 in. . .	382	315	1,191	995	3,793	9·9
IV Class. 3 ft. to 3 ft. 11 in. . . .	243	58	577	379	1,425	5·9

‡ No scantlings.

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe 4, Compartment 37, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF		TOTAL VOLUME (C. FT.) OF			Average per tree (cubic feet converted).
		SLEEPERS.					
		Narrow Gauge.	Scantlings.	Sleepers.	Scantlings.	Total.	
I Class. 6 ft. girth and over	128	2,912	81	2,831·1	137·4	2,969	23·2
II Class. 5 ft. to 5 ft. 11 in.	149	1,979	116	1,924·0	194·1	2,118	14·2
III Class. 4 ft. to 4 ft. 11 in.	107	855	43	831·3	68·8	900	8·6
IV Class. 3 ft. to 3 ft. 11 in.	16	78	9	75·8	13·8	90	5·6

SPECIES—*SHOREA ROBUSTA.*

Outturn from Coupe 4, Compartment 38, Raigarh Range, Balaghat Division, Central Provinces.

Girth.	Number of trees converted.	NUMBER OF			TOTAL VOLUME (CUBIC FEET) OF			Average per tree (cubic feet converted).
		SLEEPERS.		Scantlings.	Sleepers.	Scantlings.	Total.	
		Broad Gauge.	Narrow Gauge.					
I Class. 6 ft. girth and over .	113	20	2,801	124	2,789·2	163·4	2,953	26·1
II Class. 5 ft. to 5 ft. 11 in. .	122	3	1,791	42	1,751·2	53·4	1,805	14·8
III Class. 4 ft. to 4 ft. 11 in. .	145	12	1,318	11	1,321·0	14·4	1,335	9·2
IV Class. 3 ft. to 3 ft. 11 in. .	49	...	253	16	245·9	20·8	267	5·4

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*DALBERGIA SISSOO.*

Siwalik Division, Western Circle, United Provinces.

SAMPLE PLOT.	FOREST RESEARCH INSTITUTE SAMPLE PLOT NO. 5.
Thinned or Unthinned.	Unthinned.
Descriptive details	Pure young fully stocked crop of Shisham (*Dalbergia Sissoo*) on alluvial soil of sand and boulders. Undergrowth of *Munj* and other grasses, beginning to thin out.
Period of measurement .	1910-11 to 1915-16
Total number of measurements .	14*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	inches.
10	0	9
20	1	$9\frac{1}{4}$

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—9 measts.; 12″ to 24″—5 measts.;=14 measurements.

Record of Periodical Volume Measurements.

Siwalik Division, Western Circle, United Provinces.

No. of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.						
									Periodic yields.				Total to date.		
						Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. f
5	1910-11	*Dalbergia Sissoo* . .	6″ girth and over only. 716	8·6	20	...	191	191	...	...	...	...	...	...	...
			Under 6″ girth. 1,243												
		Total .	1,959	...	...	...	...	...	...	...	...	...	...	...	...
	1915-16	......	6″ girth and over. 1,014	11·6	27	...	787	787	27	...	24	24	...	24	24
			Under 6″ girth. 473												
6	1910-11	*Dalbergia Sissoo* . .	Trees 6″ girth and over only. 312	13·5	32	22	509	531	...	...	...	...	...	...	...
			Under 6″ girth. 38												
		Total .	350	...	...	...	...	...	...	...	...	...	...	...	...
		Acacia Catechu . . .	Trees 6″ girth and over only. 424	13·3	33	22	507	529	...	...	...	...	...	...	...
			Under 6″ girth. 32	...											
		Total .	456	...	...	...	...	...	...	...	...	...	...	...	—
		Total .	736 (6″ and over.) 70 (Under 6″)												
		Grand Total .	806	...	...	44	1,016	1,060	...	...	...	...	...	...	...
			Trees 6″ girth and over only.												
	1915-16	*Dalbergia Sissoo* . .	183	19·1	36	50	440	490	124	...	83	83	...	83	83
		Acacia Catechu . .	253	16·5	34	66	358	424	130	...	115	115	...	115	115
		Total .	436	...	...	116	798	914	254	...	198	198	...	198	198

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*ACACIA CATECHU.*

Siwalik Division, Western Circle, United Provinces.

SAMPLE PLOT.	FOREST RESEARCH INSTITUTE SAMPLE PLOT No. 6.
Thinned or Unthinned.	Unthinned.
Descriptive details	Fully stocked crop of Shisham (*Dalbergia Sissoo*) and Khair (*Acacia Catechu*) on alluvial soil of sand and boulders. Dense undergrowth of *Adhatoda Vasica*.
Period of measurement .	1910-11 to 1915-16
Total number of measurements .	45*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.
20	0 2
30	0 4½
40	0 7
50	0 9½
60	1 1½
70	1 5¾
80	1 10
90	2 2¼
100	2 6½
110	2 10

NOTE.—Nothing has been added for the time required for the seedling to establish itself.
* 0" to 12"—10 measts.; 12" to 24"—33 measts.; 24" to 36"—2 measts.;=45 measurements.

Summary of results of measurements in Divisional Sample Plots.

Species—*Acacia catechu.*

Kheri Division (Trans-Sarda Forests, Open Working Circle), Eastern Circle, United Provinces.

Sample Plot.	Sathiana block.
Thinned or Unthinned.	Unthinned.
Period of measurement .	1905–1913
Total number of measurements .	75*

Rate of growth in girth.

Age in years.	Ft. in.
20	0 8
30	1 2½
40	1 8½
50	2 2
60	2 7½
70	3 ½
80	3 6½
90	4 0
100	4 5
110	4 10
120	5 2½
130	5 7
140	5 11

Note.—Nothing has been added for the time required for the seedling to establish itself.

* 0″—12″—number of measurements *nil;* 12″ to 24″—30 measts.; 24″ to 36″—30 measts.; 36″ to 48″—11 measts.; 48″ to 60″—2 measts.; 60″ to 72″—2 measts.;=75 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*TERMINALIA TOMENTOSA.*

Gonda Division, Eastern Circle, United Provinces.

SAMPLE PLOT.	PLOTS NOS. 3, 4, 5, 7 AND 8 COMBINED.
Thinned or Unthinned.	Mixed.
Period of measurement .	1903-04 to 1915-16.
Total number of measurements .	64*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.
30	0 7½
40	0 11½
50	1 3¾
60	1 8
70	2 0
80	2 4½
90	2 9
100	3 1¼
110	3 5¾
120	3 10
130	4 3
140	4 9¼
150	5 3¾
160	5 11¼

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—3 measts.; 12″ to 24″—20 measts.; 24″ to 36″—20 measts.; 36″ to 48″—14 measts.; 48″ to 60″—6 measts.; 60″ to 72″—1 measurement; =64 measurements.

SPECIES—*TECTONA GRANDIS.*

Allapilli Reserve, South Chanda Division, Central Provinces.

Thickness of *Bark* and radial width of *Sap-wood* at 5 feet from ground-level : average based on 113 trees. Measurements carried out by the Divisional Staff 1911-12.

Girth class at 5 ft. from ground-level.	Average bark thickness.	Average radial width of sap-wood.
	inches.	inches.
0— 11″	·16	·85
1′—1′ 11″	·25	1·0
2′—2′ 11″	·31	1·1
3′—3′ 11″	·34	1·1
4′—4′ 11″	·37	1·1
5′—5′ 11″	·38	1·0
6′—6′ 11″	·38	0·9

SPECIES—*TECTONA GRANDIS.*

Allapilli Reserve, South Chanda Division, Central Provinces.

Bhimaran Hills Forests.

Rate of growth in *Girth* and in *Height* based on measurements of 33 trees carried out by the Divisional Staff about 1911-12.

Age.	Girth at 5 ft. from ground-level.		Height.
Years.	Ft.	inches.	Ft.
30	1	3	44
40	2	2	53
50	2	8	60
60	3	1	65
70	3	5	69
80	3	9	73
90	4	1	76
100	4	4	79
110	4	7	81
120	4	10	83
130	5	1	85
140	5	4	86
150	5	6	87

SPECIES—*TECTONA GRANDIS.*

Allapilli Reserve, South Chanda Division, Central Provinces.
Bhimaran Plains Forests.

Rate of growth in *Girth* and in *Height* based on measurements of 43 trees carried out by the Divisional Staff about 1911-12.

Age.	Girth at 5 ft. from ground-level.		Height.
Years.	Ft.	inches.	Ft.
40	3	0	69
50	3	8	73
60	4	1	75
70	4	5	77
80	4	8	78
90	4	11	79
100	5	1	80
110	5	3	81
120	5	5	81
130	5	7	82
140	5	9	82
150	5	11	83

SPECIES—*TECTONA GRANDIS.*

Allapilli Reserve, South Chanda Division, Central Provinces.
Mirculloo Block, Allapilli Range.

Rate of growth in *Girth* and in *Height* based on measurements of 42 trees carried out by the Divisional Staff about 1911-12.

Age.	Girth at 5 ft. from ground-level.		Height.
Years.	Ft.	inches.	Ft.
30	1	2	36
40	1	11	64
50	2	10	72
60	3	5	76
70	3	10	78
80	4	1	80
90	4	4	82
100	4	7	84
110	4	10	86
120	5	1	88
130	5	4	89
140	5	7	90
150	5	9	91

Volume Table showing Outturn of Teak timber in compartments 2, 3, 4 and 5, Allapilli Rang South Chanda Division, Central Provinces (from detailed figures supplied by the Divisiona Forest Officer).

The following table gives the results of measurements of timber from naturally-grown tea trees felled in compartments 2, 3, 4 and 5, Allapilli Range, South Chanda Divisio Central Provinces, for some years prior to 1913.

No. of trees measured.	Girth Class.	Average girth at breast-height.	Average outturn per tree (solid cubic feet round timber measured over bark by quarter-girth-squared measure). Sound Logs. 50 c. ft. in vol. and over. No.	Vol.	Under 50 c.ft. in vol. No.	Vol.	Total. No.	Vol.	Unsound Logs. 50 c.ft. and over. No.	Vol.	Under 50 c.ft. No.	Vol.	Total. No.	Vol.	Total sound and unsoun logs of all dimension No.	Vol
				c. ft.		c. ft.		c. ft.		c. ft.		c. ft.		c. ft.		c. f
								I. Sound trees.								
137	6′–6′ 11″	6′ 4″	·08	4·46	1·38	34·6	1·46	39·06	...	...	...	...	2·44	31·07	3·90	70·
106	7′–7′ 11″	7′ 4″	·25	14·6	1·48	41·15	1·73	55·75	...	...	...	...	1·88	35·88	3·61	91·
65	8′–8′ 11″	8′ 2″	·38	22·8	1·13	29·61	1·51	52·41	...	...	...	...	2·93	65·32	4·44	117·
25	9′–9′ 11″	9′ 5″	·36	24·91	·76	18·5	1·12	43·41	...	...	...	...	3·56	95·47	4·68	138·
10	10′–10′ 11″	10′ 4″	·4	28·26	1·1	30·61	1·5	58·87	...	...	...	...	5·2	120·46	6·7	179·
3	11′–11′ 11″	11′ 4″	1·0	69·4	1·33	32·6	2·33	102	...	...	...	...	2·67	76·23	5	178·
4	12′–12′ 11″	12′ 2″	·75	57·92	1·25	25·3	2	83·22	...	...	...	...	7·0	156·92	9	240·
1	13′–13′ 11″	13′ 6″	...	...	4	80·6	4	80·6	...	...	...	...	1	73·6	5	154·
								II. Unsound trees.								
132	6′–6′ 11″	6′ 4″	...	...	...	...	·90	22·19	·03	1·70	2·95	43·27	2·98	44·97	3·88	67
97	7′–7′ 11″	7′ 4″	...	...	...	..	1·15	32·9	·22	13·52	2·68	45·68	2·90	59·2	4·05	92
60	8′–8′ 11″	8′ 4″	...	...	...	...	1·01	32·34	·25	16·91	3·42	59·57	3·67	76·48	4·68	108
30	9′–9′ 11″	9′ 3″	...	...	...	...	1·03	33·17	·57	36·25	3·27	61·75	3·84	98	4·87	131
11	10′–10′ 11″	10′ 5′	...	...	...	...	1·36	42·74	·36	24·85	4·09	62·4	4·45	87·25	5·81	129
9	11′–11′ 11″	11′ 6″	...	...	...	...	1·67	44·93	1·22	86·26	3·56	61·33	4·78	147·59	6·45	19
3	12′–12′ 11″	12′ 5″	...	...	...	...	1·67	65·3	1·67	110·37	3	44·57	4·67	154·94	6·34	22
2	13′–13′ 11″	13′ 0″	...	...	...	...	...	...	·5	53·35	7	144·6	7·5	197·95	7·5	197

(1) The classification into sound and unsound trees was made at the time of selection of the trees for felling, irrespective of unsoundness which may have become apparent after felling.

(2) It is not clear from the records to what extent the classification of logs into "sound" and "unsound" is to be considered corr possibly some of the logs classed as unsound ought to be considered as sound.

Method of using curves showing growth of TECTONA GRANDIS.

Example 1.—Bhimaran Hills Forest.

To find at what age a pole 30 feet long and 6 inches in diameter at the to will be produced, run the eye along the horizontal line starting from the 6 inch point on the vertical axis till it meets the 30-foot curve, then follow down th vertical line from this point to the horizontal axis and read 56 (age in years).

Example 2.—Bhimaran Hills Forest.

To find the ages at which sleepers 10 feet long are produced (assuming t trees are felled at ground-level).—If $14\frac{1}{2}$ inches is the minimum top diameter logs yielding 2 B. G. sleepers, run the eye along the horizontal line starting fro the $14\frac{1}{2}$ inches point on the vertical axis and note the ages at which it cuts t curves. Two sleepers are available at 109 years, four at 122, six or more at 14 eight or more at 156.

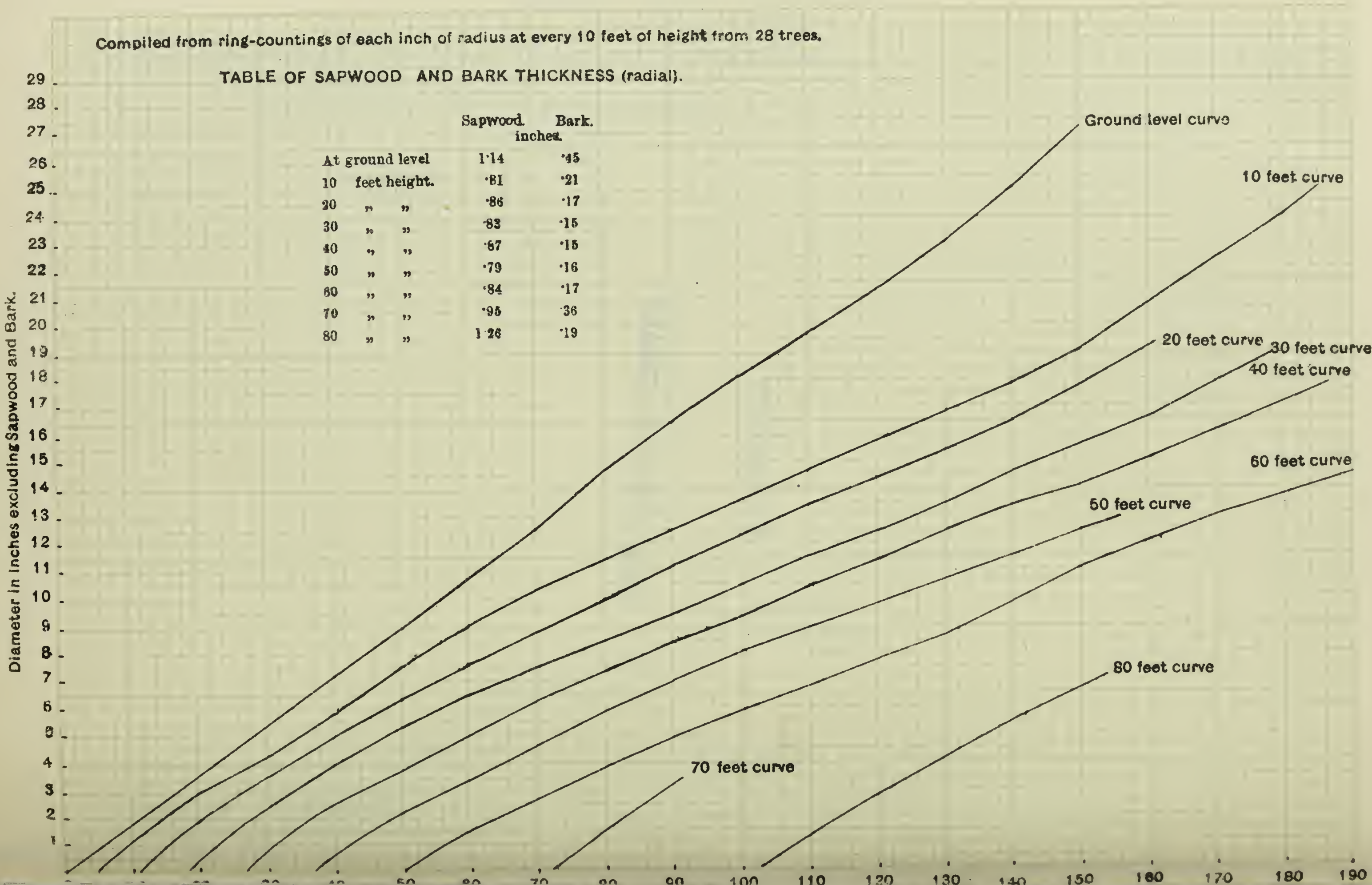
Statistics compiled in Silviculturist's office.

CURVES SHOWING GROWTH OF *TECTONA GRANDIS*
IN
BHIMARAM HILLS FOREST
ALLAPILLI, SOUTH CHANDA, C. P.

Compiled from ring-countings of each inch of radius at every 10 feet of height from 28 trees.

TABLE OF SAPWOOD AND BARK THICKNESS (radial).

	Sapwood.	Bark.
	inches.	
At ground level	1·14	·45
10 feet height.	·81	·21
20 " "	·86	·17
30 " "	·83	·15
40 " "	·67	·15
50 " "	·79	·16
60 " "	·84	·17
70 " "	·95	·36
80 " "	1·26	·19



Statistics compiled in Silviculturist's office.

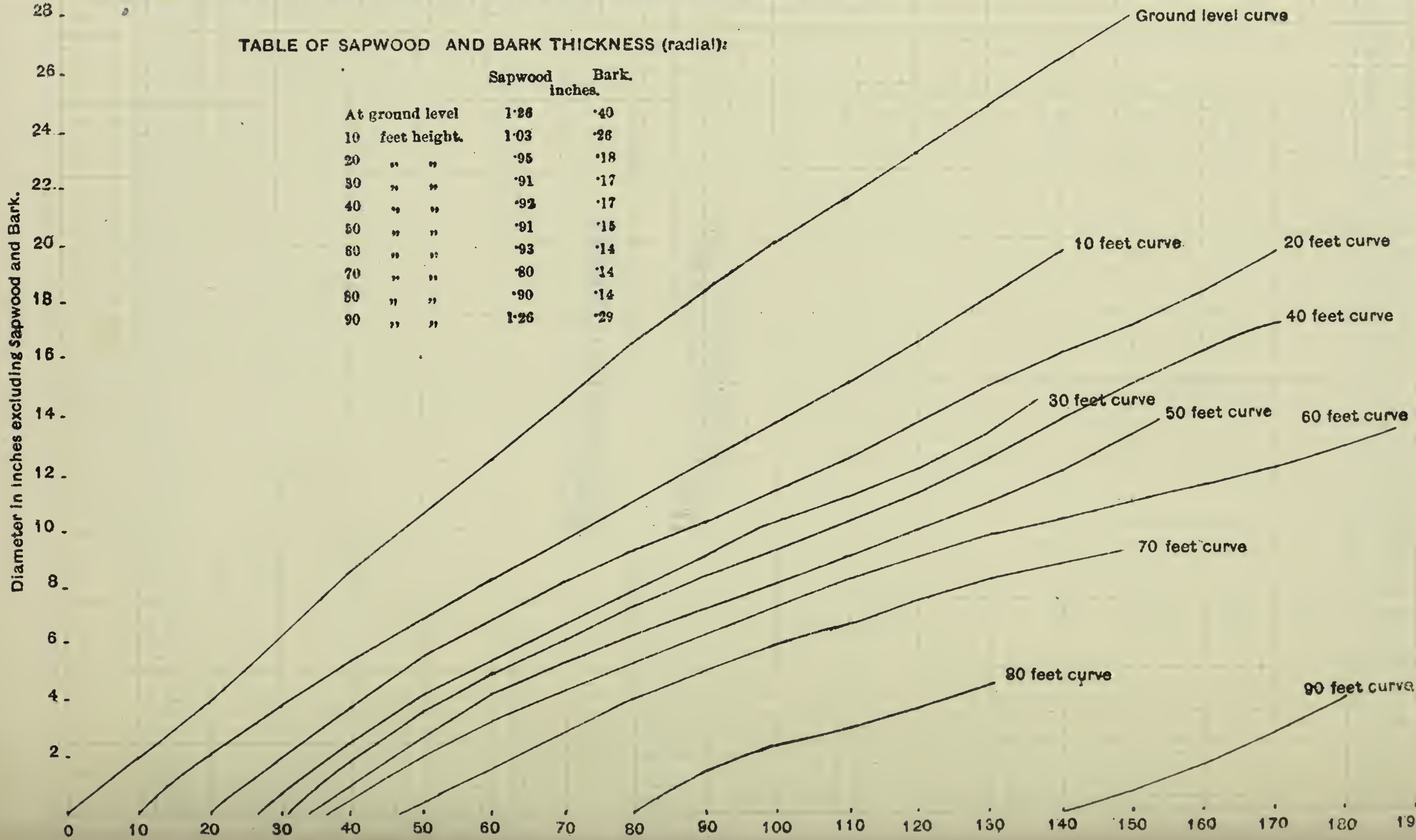
PLATE 3.

CURVES SHOWING GROWTH OF *TECTONA GRANDIS* IN MIRCULLOO FOREST, ALLAPILLI, SOUTH CHANDA, C. P.

Compiled from ring-countings of each inch of radius at every 10 feet of height from 34 trees.

TABLE OF SAPWOOD AND BARK THICKNESS (radial):

	Sapwood (inches)	Bark (inches)
At ground level	1·28	·40
10 feet height	1·03	·26
20 " "	·95	·18
30 " "	·91	·17
40 " "	·92	·17
50 " "	·91	·15
60 " "	·93	·14
70 " "	·80	·14
80 " "	·90	·14
90 " "	1·26	·29



SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*QUERCUS DILATATA.*

Naini Tal Division, Kumaun Circle, United Provinces.

SAMPLE PLOT.	NOS. 9, 10, 11, 12, 27 AND 28 COMBINED.
Thinned or unthinned.	Unthinned.
Period of measurement	1911-12 to 1915-16
Total number of measurements . . .	253*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.
30	1 0
40	1 5½
50	1 11¼
60	2 6¼
70	3 2
80	3 9½

Note.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—number of measurements *nil;* 12″ to 24″—238 measts.; 24″ to 36″—10 measts.; 36″ to 48″—5 measts.; =253 measurements.

RECORD OF PERIODICAL VOLUME MEASUREMENTS.

Naini Tal Division, Kumaun Circle, United Provinces.

No. of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.						
									Periodic yields				Total to date.		
						Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft
9	1911-12	*Quercus dilatata* . .	12″ & over 1,144	17·6	41	...	3,338	3,338	...	...	...	...	...	...	...
			6″ to 12″ 956	8·8	24	...	411	411	...	...	...	...	...	...	...
		Total .	2,100	average 13·6	average 33	...	3,749	3,749	...	...	...	...	...	...	...
	1915-16		12″ & over 989	19·8	41	...	3,196	3,196	344	...	805	805	...	805	80
			6″ to 11″ 478	9·0	21	...	200	200							
		Total .	1,467	17·1	37	...	3,396	3,396	...	...	...	...	...	...	...
10	1911-12	*Quercus dilatata* . .	12″ & over 530	20·5	47	...	2,499	2,499	110	...	(Dominant and dominated only) 389	389	...	389	3
			6″ to 12″ 160	9·7	28	...	93	93	350	...	(Suppressed and dead only) 361	361	...	361	3
		Total .	690	average 18·0	average 43	...	2,592	2,592	460	...	750	750	...	750	7
	1915-16		12″ & over 550	23·2	39	...	3,251	3,251	40	...	225	225	...	975	9
			6″ to 11″ 100	9·5	22	...	46	46							
		Total .	650	21·7	39	...	3,297	3,297	...	...	...	...	...	...	...

RECORD OF PERIODICAL VOLUME MEASUREMNTS—*contd.*

Naini Tal Division, Kumaun Circle, United Provinces—contd.

	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet. Timber over 24″ in girth.	Small wood 6″–24″ in girth.	Total.	Intermediate yields per acre from thinnings. Periodic yields. Number of stems.	Timber over 24″ in girth.	Small wood 6″–24″ in girth.	Total.	Total to date. Timber over 24″ in girth.	Small wood 6″–24″ in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
1	1911-12	*Quercus dilatata* . .	12″ & over 525	15·0	30	...	777	777	...	...	...	...	...	...	...
			6″ to 12″ 1,725	8·3	21	...	431	431		...	...	...	...	...	..
			4″ to 6″ 1,200	...	...	...	...	...	...	...	...	...	...	...	...
		Total .	3,450	average 9·9	average 23	...	1,208	1,208	...	...	...	...	...	...	...
	1915-16		13″ & over 525	17·5	30	...	1,177	1,177	550	...	370	370	...	370	370
			6″ to 12″ 1,050	8·6	24	...	390	390							
		Total .	1,575	12·4	31	...	1,567	1,567	...	...	...	...	...	...	...
12	1911-12	*Quercus dilatata* . .	12″ & over 614	14·3	36	...	955	955	...	...	...	...	...	...	...
			6″ to 12″ 2,586	8·5	25	...	1,148	1,148	...	...	...	...	...	...	...
			4″ to 6″ 1,343	...	...	...	...	...	...	...	...	...	...	...	...
		Total .	4,543	average 9·6	average 27	...	2,103	2,103	...	...	...	...	...	...	...
	1915-16		14″ & over 614	16·8	34	...	1,401	1,401	...	...	...	...	...	...	...
			6″ to 13″ 2,714	9·5	25	...	1,324	1,324	...	...	..	...	...	...	...
		Total .	3,328	11·2	31	...	2,725	2,725	...	...	...	...	...	...	...

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*concld.*

Naini Tal Division, Kumaun Circle, United Provinces—concld.

No. of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Intermediate yields per acre from thinnings. Periodic yields. Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Total to date. Timber over 34″ in girth.	Small wood 6″—24″ in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
27	1911-12	*Quercus dilatata* . .	12″ & over 1,000	14·7	36	...	1,555	1,555	...	...	...	...	...	...	...
			6″ to 12″ 1,940	9·0	25	...	861	861	...	...	...	...	...	...	...
		Total .	2,940	average 10·9	average 29	...	2,416	2,416	...	...	...	...	...	...	...
	1915-16		12″ & over 1,140	16·0	33	...	1,786	1,786	540	...	530	530	...	530	530
			6″ to 11″ 1,040	8·5	22	...	390	390							
		Total .	2,180	13·0	31	...	2,176	2,176	...	...	...	...	...	...	...
									(Dominant and dominated only)						
28	1911-12	*Quercus dilatata* . .	12″ & over 950	16·0	30	...	1,684	1,684	200	...	333	333	...	333	333
									(Suppressed and dead only)						
			6″ to 12″ 725	9·2	25	...	342	342	1,300	...	1,022	1,022	...	1,022	1,022
		Total .	1,675	average 13·0	average 28	...	2,026	2,026	1,500	...	1,355	1,355	...	1,355	1,355
	1915-16		11″ & over 1,250	16·8	32	...	2,100	2,100	175	...	142	142	...	1,497	1,497
			6″ to 10″ 200	8·1	24	...	77	77							
		Total .	1,450	16·0	30	...	2,177	2,177	...	...	...	...	...	....	...

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS
SPECIES—*QUERCUS INCANA.*

Naini Tal and West Almora Divisions, Kumaun Circle, United Provinces.

SAMPLE PLOT.	No. 2.	No. 20.	No. 22.	No. 24.	PLOTS COMBINED.
Thinned or Unthinned.	Thinned.	Thinned.	Thinned.	Thinned.	Thinned.
Descriptive details.	North aspect, moderate slope, good loamy soil with small boulders. Good quality forest of *Quercus incana*, fairly heavily thinned. Density ·7. Fair amount of shrubby undergrowth, and coppice of rhododendron and miscellaneous species.	Aspect north-east, slope moderate, rock-quartzitic mica schist. Soil clayey loam. Even-aged pole crop. Density ·9.	Aspect east, slope moderate. Even-aged big pole crop. Density ·9. Rock quartzitic mica schist. Soil fertile loam.	Aspect east, slope steep. Rock quartzitic mica schist. Soil loamy with some gravel. Even-aged big pole crop. Density full.	
Period of measurement.	1910-11 to 1915-16.	1911-12 to 1915-16.	1911-12 to 1915-16.	1911-12 to 1915-16.	
Total number of measurements.	51	52	52	57	212*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
30	1	0¼	0	6	0	9½	0	11	0	7¾
40	1	5¼	0	9	1	1¼	1	3¾	0	11
50	1	10¼	1	0	1	5	1	8¼	1	2½
60	2	3¼	1	3	1	9	2	1	1	6½
70	2	8½	1	6	2	1	2	6	1	10¼
80	...		1	9¼	2	5½	2	11¼	2	3½
90	...		2	0¼	2	10½	...		2	8½
100	...		2	4½	...		...		...	
110	...		2	8¼	...		...		...	

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—11 measts. ; 12″ to 24″—166 measts. ; 24″ to 36″—35 measts. ;=212 measurements.

Summary of results of measurements in Forest Research Institute Sample Plots
Species—*Quercus incana*—concld.

Naini Tal and West Almora Divisions, Kumaun Circle, United Provinces.

Sample Plot.	No. 1.	No. 3.	No. 4.	No. 6.	No. 19.	No. 21.	No. 23.	Plots combined.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details	Aspect south-east, in well sheltered valley, slope easy; soil fertile gravelly loam; rather scanty shrubby undergrowth; reproduction absent. Bán oak in tree stage. Density about ·7.	South aspect, moderate slope, well sheltered valley. Soil good, loamy, with small boulders. Scanty undergrowth, of shrubs. Bán oak forest in pole stage, much of it old coppice. Density ·9.	Gentle slope to south, in sheltered ravine. Good loamy soil with small boulders. Bán oak in large pole or small tree stage. Sizes and distribution somewhat irregular, but area fully stocked on whole. A fair quantity of shrubby undergrowth.	Aspect south-west, sheltered valley, moderate slope, soil shaly loam. Forest of Bán oak of good quality in pole stage. Density ·9. Undergrowth scanty shrubby.	Aspect north-east, slope moderate. Rock quartzitic mica schist, soil clayey loam. Even-aged pole crop. Density ·9.	Aspect south-east, slope moderate. Rock quartzitic mica schist. Soil rather rocky in parts, but with fertile loam elsewhere and between the boulders. Even-aged pole crop. Density ·95.	Aspect north and west, slope moderate. Rock quartzitic mica schist. Soil loam with some gravel on end of spur in valley. Big pole crop. Density full.	
Period of measurement.	1910-11 to 1915-16	1910-11 to 1915-16	1910-11 to 1915-16	1910-11 to 1915-16	1911-12 to 1915-16	1911-12 to 1915-16	1911-12 to 1915-16	...
Total number of measurements.	69	51	46	74	65	53	84	442*

Rate of growth in girth.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
30	0	7¼	0	9¼	0	9¾	0	10	0	6¼	0	6	0	7¾	0	8
40	0	10½	1	1½	1	2¼	1	2½	0	9¾	0	9½	1	0	1	0¼
50	1	1¾	1	5¾	1	6¾	1	7¼	1	1¼	1	1	1	4¾	1	4½
60	1	5¼	1	10¼	1	11¼	2	0¼	1	5	1	4¾	1	9¼	1	9
70	1	8¾	2	3½	2	3¾	2	5¼	1	8¾	1	8¾	2	3	2	1½
80	2	0½	...		2	8¾	2	10½	...		2	0¾	2	10	2	6½
90	2	4½	...		3	1½	...		...		2	4¾	3	5½	2	11½
100	2	9¼	...		3	6½	...		...		...		...		3	4½
110	...		...		3	11½	...		...		...		...		3	9½
120	...		...		...		...		...		...		...		4	2½

Note.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—58 measts.; 12″ to 24″—320 measts.; 24″ to 36″—56 measts.; 36″ to 48″—8 measts.; = 442 measurements.

RECORD OF PERIODICAL VOLUME MEASUREMENTS.

Naini Tal Division, Kumaun Circle, United Provinces.

No. of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at $4\frac{1}{2}'$ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.						
									Periodic yields.				Total to date.		
						Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.
				(inches)						c. ft.	c. ft.	c. ft.	c.ft.	c.ft.	c.ft.
1	1910-11	*Quercus incana*	378	22·3	44	...	...	2,309	...	...	...	...	...	...	...
	1915-16		311	27·3	50	...	...	2,668	43	...	...	187	...	...	187
2	1910-11	Ditto	265	23·4	42	...	...	1,559	...	...	...	...	...	...	...
	1915-16		287	25·7	45	...	...	2,289	...	...	...	...	...	...	...
3	1910-11	Ditto	1,451	11·4	33	...	1,866	1,866	...	...	...	...	...	...	...
	1915-16		718	15·8	31	...	1,873	1,873	718	...	...	613	...	...	613
4	1910-11	Ditto	967	15·9	36	...	2,678	2,678	...	...	...	...	...	...	...
	1915-16		674	19·0	47	...	2,164	2,164	174	...	...	778	...	...	778
5	1910-11	Ditto	1,969	8·1	19	...	275	275	...	...	...	...	...	...	...
	1915-16		1,020	10·0	24	...	531	531	390	...	...	98	...	...	98
6	1910-11	Ditto	1,414	11·8	25	...	1,539	1,539	...	...	...	...	...	...	...
	1915-16		982	15·5	30	...	1,512	1,512	385	...	...	252	...	...	252

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*contd.*

West Almora Division, Kumaun Circle, United Provinces.

No. of Sample Plot.	Year of measurement.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet. Timber over 24″ in girth.	Volume per acre in solid cubic feet. Small wood 6′—24″ in girth.	Volume per acre in solid cubic feet. Total.	Intermediate yields per acre from thinnings. Periodic yields. Number of stems.	Periodic yields. Timber over 24″ in girth.	Periodic yields. Small wood 6″—24″ in girth.	Periodic yields. Total.	Total to date. Timber over 24″ in girth.	Total to date. Small wood 6″—24″ in girth.	Total to date. Total.
				(inches)						c. ft.	c. ft.	c. ft.	c.ft.	c.ft.	c.ft.
19	1911-12	*Quercus incana*	1,722	11·3	30	...	1,772	1,772	...	...	...	...	...	...	...
	1915-16	Ditto	11″ and over 1,025	15·0	32	...	2,176	2,176	...	...	...	...	...	...	...
			6″ to 11″ 542	8·4	17	...	165	165	...	...	...	...	...	...	...
		Total	1,567	13·1	30	...	2,341	2,341	...	...	...	...	...	...	...
									(Dominant and dominated only.)						
20	1911-12	*Quercus incana*	11″ and over 622	17·2	38	...	1,703	1,703	123	...	222	222	...	222	222
									(Suppressed and dead only)						
			8″ to 11″ 104	9·4	24	...	46	46	734	...	478	478	...	478	478
		Total	726	average 16·1	average 36	...	1,749	1,749	857	...	700	700	...	700	700
	1915-16	*Quercus incana*	11″ and over 572	18·5	37	...	1,590	1,590	112	...	86	86	...	786	786
21	1911-12	Ditto	12″ and over 610	16·8	33	...	1,536	1,536	...	...	...	...	...	...	...
			6″ to 12″ 553	9·1	28	...	281	281	...	...	...	...	...	...	...
		Total	1,163	average 13·1	average 30	...	1,817	1,817	...	...	...	...	...	...	...
	1915-16	*Quercus incana*	12″ and over 797	17·5	35	...	1,857	1,857	...	...	...	...	...	...	...
			6″ to 12″ 356	9·2	18	...	129	129	...	...	...	...	...	...	...
		Total	1,153	15·5	31	...	1,986	1,986	...	...	...	...	...	...	...

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*concld.*

West Almora Division, Kumaun Circle, United Provinces—concld.

No. of Sample Plot.	Year of measurement.	SPECIES.	Number of stems per acre.	Mean girth at 4½' from ground.	Mean height of crop in feet.	VALUE PER ACRE IN SOLID CUBIC FEET. Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	TOTAL TO DATE. Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.
				(inches						c.ft.	c. ft.	c. ft.	c.ft.	c.ft	c.ft.
									(Dominant and dominated only.)						
22	1911-12	*Quercus incana*	11" and over 590	16·2	35	...	1,372	1,372	60	...	216	216	...	216	216
									(Suppressed and dead only.)						
			under 11" 29*	9·0	28	...	14	14	530	...	279	279	...	279	279
									70	...	73	73	...	73	73*
									270	...	338	338	...	338	338†
		Total .	619	average 15·8	average 34	...	1,386	1,386	870	...	690	690	...	690	690
							Grand	Total	930	...	906	906	...	906	906
	1915-16	*Quercus incana*	580	18·0	31	...	1,189	1,189	40	...	22	22	...	928	928
23	1911-12	Ditto .	12" and over 539	17·3	37	...	1,602	1,602	...	...	...	...	...	...	...
			6" to 12" 461	9·6	28	...	234	234	...	...	...	...	...	...	...
		Total .	1,000	average 13·8	average 33	...	1,836	1,836	...	...	...	...	...	...	...
	1915-16	*Quercus incana*	12" and over 666	18·5	37	...	2,026	2,026	...	...	...	...	...	...	...
			6" to 12" 351	9·3	21	...	111	111	...	...	...	...	...	...	...
		Total .	1,017	16·0	36	...	2,137	2,137	...	...	...	...	...	...	...
									(Dominant and dominated only.)						
24	1911-12	*Quercus incana*	12" and over 458	17·3	36	...	1,403	1,403	64	...	257	257	...	257	257
									(Suppressed and dead only)						
			6" to 12" 285	9·1	28	...	131	131	414	...	330	330	...	330	330
									271	...	162	162	...	162	162
		Total .	743	average 14·2	average 33	...	1,534	1,534	685	...	492	492	...	492	492
							Grand	Total	749	...	749	749	...	749	749
	1915-16	*Quercus incana*	12" and over 457	19·3	38	...	1,380	1,380	193	...	108	108	...	857	857
			6" to 12" 57	10·1	28	...	28	28	...	...	...	...	...	...	...
		Total .	514	18·6	35	...	1,408	1,408	...	...	...	...	...	...	...

* Rhododendron. † Other species.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*PINUS LONGIFOLIA.*

Naini Tal Division, Kumaun Circle, United Provinces.

SAMPLE PLOT.	BHOWALI COMPTT. 18.	NALENA COUPE 12.
Thinned or Unthinned.	Unthinned.	Unthinned.
Period of measurement	1899-1915.	1899-1915.
Total number of measurements	76*	131†

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.
10	...	...	...	...
20	0	6¼	0	5
30	0	8½	0	9
40	1	1¾	1	1½
50	1	7	1	6
60	2	0¼	1	10½
70	2	5¼	2	3½
80	2	10¼	2	9¼
90	3	3	3	4¼
100	3	7¼	3	11¼
110	3	11	4	6¾
120	4	2	5	2¾
130	4	6	5	11½
140	4	9½		
150	5	0¼		
160	5	3½		
170	5	6¾		
180	5	9		
190	6	0½		
200	6	3½		

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—15 measts.; 12″ to 24″—35 measts.; 24″ to 36″—6 measts.; 36″ to 48″—2 measts.; 48″ to 60″—12 measts.; 60″ to 72″—4 measts.; 72″ to 84″—1 meast.; 84″ to 96″—number of measurements *nil*; 96″ to 108″—1 meast.;=76 measurements.

† 0″ to 12″—Number of measurements *nil*; 12″ to 24″—13 measts.; 24″ to 36″—59 measts.; 36″ to 48″—50 measts.; 48″ to 60″—8 measts.; 60″ to 72″—1 meast.;=131 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*PINUS LONGIFOLIA—contd.*

Naini Tal Division, Kumaun Circle, United Provinces.

SAMPLE PLOT.	No. 14.	No. 15.	No. 17.	No. 25.	PLOTS, 8, 14, 15, 17 AND 25, COMBINED.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details.	Elevation about 5,200′. Aspect east, slope gentle. Even-aged large pole crop. Density before thinning ·9. Rock mica-schist with fragments of quartz.	Aspect south-west, slope moderate. Rock mica schist with fragments of quartz. Soil clayey with much gravel. Even-aged young pole crop. Younger than S. P. No. 13 and 14. Density ·9.	Aspect north-east on old cultivation, almost flat ground. Rock mica schist. Soil micaceous loam with some gravel of quartzite fragments. Even-aged big pole crop. Density ·9	Slope, gentle, on former cultivation. Rock quartzitic mica-schist. Soil micaceous, sandy loam with much gravel ; big pole crop of not good quality, many of the poles inclined to have twisted fibre, as a large proportion of trees are in the surrounding forests. Density ·95.	
Period of measurement.	1911-12 to 1915-16.	1911-12 to 1915-16.	1911-12 to 1915-16.	1911-12 to 1915-16.	
Total number of measurements.	66	98	57	140	370·*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
30	0	4¾	0	8	0	5½	0	5¼	0	10
40	0	7¾	1	0¼	0	9	0	8½	1	1
50	0	10	1	4½	1	0¾	1	0	1	5
60	1	1½	1	9	1	4½	1	3½	1	9
70	1	5			1	8½	1	7	2	1
80	1	8			2	0¾	1	10½	2	6
90	2	0			2	6	2	2¼	2	11
100	2	3½			3	0	2	7½	3	5½
110	2	8			3	6½	3	1	4	2
120	3	1					3	7	4	8½
130	3	6½					4	1		
140							4	6¼		
150							4	11½		

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—29 measts. ; 12″ to 24″—232 measts. ; 24″ to 36″—94 measts. ; 36″ to 48″—14 measts.; 48″ to 60″—1 measurement ; = 370 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS—*contd.*

SPECIES—*PINUS LONGIFOLIA—contd.*

West Almora Division, Kumaun Circle, United Provinces.

SAMPLE PLOT.	Baldhoti Reserve Comptt. No. 1.	Baldhoti C. 4.	PLOTS COMPTT. 1 AND COMPTT. 4 COMBINED.
Thinned or Unthinned	Unthinned.	Unthinned.	Unthinned.
Period of measurement . . .	1903 to 1915	1903 to 1915	1903 to 1915
Total number of measurements . .	70	98	168*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.
10	0	5	0	1¼	0	5
20	0	10¾	0	4¾	0	10¾
30	1	1¼	0	9½	1	4¼
40	1	9¾	1	2¼	1	9¾
50	2	4½	1	8	2	4½
60	3	0¼			3	0¼
70	3	10			3	10

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—74 measts.; 12″ to 24″—78 measts.; 24″ to 36″—15 measts.; 36″ to 48″—1 measurement ; = 168 measurements.

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS—*concld.*

SPECIES—*PINUS LONGIFOLIA*—*concld.*

West Almora Division, Kumaun Circle, United Provinces.

SAMPLE PLOT.	No. 13.	No. 16.	No. 18.	No. 26.	Plots 7, 13, 16, 18 and 26, combined.
Thinned or Unthinned.	Thinned.	Thinned.	Thinned.	Thinned.	Thinned.
Descriptive details.	Elevation about 5,200 ft. Aspect east. Slope gentle. Even-aged large pole crop. Density before thinning, ·9. Rock mica schist with fragments of quartz.	Aspect south-west. Slope mod. Rock mica-schist with fragments of quartz. Soil clayey with much gravel. Even-aged young pole crop. Younger than sample plot Nos. 13 and 14. Density ·9.	Aspect north-east on old cultivation, almost flat ground. Rock mica schist. Soil micaceous loam with some gravel of quartzitic fragments. Even-aged big pole crop. Density ·9.	Slope gentle, on former cultivation. Rock quartzitic mica schist. Soil micaceous sandy loam with much gravel, big pole crop of quality not good. Many of the poles inclined to have twisted fibre as a large proportion of trees are in the surrounding forests. Density ·95.	
Period of measurement.	1911-12 to 1915-16.	1911-12 to 1915-16.	1911-12 to 1915-16.	1911-12 to 1915-16.	
Total number of measurements.	59	60	43	74	264*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
30	0	10	1	0	0	10	0	8¾	0	10
40	1	2	1	5½	1	1¾	1	0¾	1	3
50	1	6¼	1	11½	1	6	1	4½	1	8
60	1	10½	2	6¼	1	10¼	1	8¼	2	1½
70	2	2¾	...	...	2	2¾	2	0½	2	7
80	2	7¾	...	...	2	8	2	4½	3	0
90	3	1½	...	...	...	...	2	9½	3	6
100	3	7¼	...	...	...	...	3	2¾	4	0
110	...	...	...	...	...	...	3	8½	...	...

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

* 0″ to 12″—Number of measts. *nil* ; 12″ to 24″—157 measts. ; 24″ to 36″—87 measts. ; 36″ to 48″—20 measts. ; = 264 measurements.

RECORD OF PERIODICAL VOLUME MEASUREMENTS.

Naini Tal Division, Kumaun Circle, United Provinces.

No. of Sample Plot.	Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½' from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET. Timber over 24" girth.	Small wood 6"—24" in girth.	Total.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	TOTAL TO DATE. Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.
		(years)			(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
				13" and over							(Dominant and dominated only.)					
7	1911-12	25	*Pinus longifolia*	290	17·2	36	...	648	618	200	...	17	17	...	17	17
				6" to 13"							(Suppressed and dead only.)					
				720	12·4	31	...	779	779	480	...	17	17	...	17	17
			Total	1,010	average 13·8	average 32	...	1,427	1,427	680	...	34	34	...	34	34
	1915-16	28	*Pinus longifolia.*	700	18·0	39	...	1,593	1,593	270	...	294	294	...	328	328
				13" and over												
8	1911-12	25	Ditto	90	16·5	32	...	188	188	...	...	...	...	...	...	...
				6" to 13"												
				1,630	10·9	26	...	1,146	1,146	...	...	...	...	...	...	...
				3" to 6"												
				860	...	...	...	...	...	...		...	...	...	...	...
			Total	2,580	average 11·2	average 26	...	1,334	1,334	...	...	...	...	...	...	...
				13" and over												
	1915-16	...	*Pinus longifolia*	540	17·6	33	...	1,235	1,235	...	...	...	...	...	...	...
				6" to 13"												
				1,220	8·9	17	...	357	357	...	..	...	...	...	...	...
			Total	1,760	13·3	31	...	1,592	1,592	...	...	...	...	...	...	...

RECORD OF PERIODICAL VOLUME MEASUREMENTS—*contd.*

West Almora Division, Kumaun Circle, United Provinces.

No. of Sample Plot.	Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre	Mean girth at 4½' from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET. Timber over 24" in girth.	VOLUME PER ACRE IN SOLID CUBIC FEET. Small wood 6"—24" in girth.	VOLUME PER ACRE IN SOLID CUBIC FEET. Total.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	PERIODIC YIELDS. Timber over 24" in girth.	PERIODIC YIELDS. Small wood 6"—24" in girth.	PERIODIC YIELDS. Total.	TOTAL TO DATE. Timber over 24" in girth.	TOTAL TO DATE. Small wood 6"—24" in girth.	TOTAL TO DATE. Total.
		(years)			(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
											(Dominant and dominated only.)					
13	1911-12	50	*Pinus longifolia*	227	32·1	64	2,016	917	2,933	66	207	250	457	207	250	457
											(Suppressed and dead only.)					
				...	...	...	...	...	...	50	...	123	123	...	123	123
				...	...	...	...	...	...	116	207	373	580	207	373	580
	1915-16	54		208	34·6	64	1,996	994	2,990	22	...	168	168	207	541	748
14	1911-12	50	Ditto	19" and over 388	29·1	61	2,846	1,646	4,492	...	...	...	...	...	...	...
				12" to 19" 86	16·2	40	...	168	168	...	...	...	...	...	...	...
			Total	474	26·8	57	2,846	1,814	4,660	...	...	...	...	...	...	...
	1915-16	54	*Pinus longifolia*	293	32·6	64	2,406	1,381	3,787	164	...	883	883	...	883	883
15	1911-12	32	Ditto	10" and over 688	16·7	42	...	1,635	1,635	...	...	...	...	...	...	...
				6" to 10" 740	7·9	21	...	185	185	...	...	...	...	...	...	...
			Total	1,428	12·1	31	...	1,820	1,820	...	...	...	...	...	...	...
	1915-16	36	*Pinus longifolia*	1,208	13·7	35	...	2,022	2,022	240	...	428	428	...	428	428
											(Dominant and dominated only.)					
16	1911-12	32	Ditto	15" and over 411	19·3	42	47	1,474	1,521	89	...	167	167	...	167	167
											(Suppressed and dead only.)					
				6" to 15" 370	10·9	25	...	241	241	301	...	134	134	...	134	134
			Total	781	average 15·3	average 34	47	1,715	1,762	390	...	301	301	...	301	301
	1915-16	36	*Pinus longifolia*	637	18·2	37	179	1,725	1,804	107	...	82	82	...	383	383

Record of Periodical Volume Measurements—*concld.*

West Almora Division, Kumaun Circle, United Provinces.

Number of Sample Plot.	Year of measurement.	Age of crop.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Intermediate yields per acre from thinnings. Periodic yields. Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Total to date. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.
		(years.)			(inches)						c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
				18″ and over								(Dominant and dominated only.)				
18	1911-12	50	*Pinus longifolia*	442	24·3	54	768	2,381	3,149	97	...	436	436	...	436	436
				9″ to 18″								(Suppressed and dead only.)				
				248	14·4	30	...	334	334	212	...	212	212	...	212	21
			Total	690	average 20·8	average 45	768	2,715	3,483	309	...	648	648	...	648	648
	1915-16	54	*Pinus longifolia.*	496	25·4	57	966	1,927	2,893	159	...	557	557	...	1,205	1,20
				15″ and over												
25	1911-12	58	Ditto	391	24·3	54	1,466	1,429	2,895	...	...	...	...	...	...	...
				14″ & under												
				114	12·7	24	...	114	114	...	...	...	...	...	...	...
			Total	505	21·7	48	1,466	1,543	3,009	...	...	...	...	...	...	...
	1915-16	62	*Pinus longifolia.*	228	31·5	59	1,519	837	2,356	262	85	779	864	85	779	86
				18″ and over								(Dominant and dominated only.				
26	1911-12	58	Ditto	193	31·5	61	1,611	619	2,230	21	36	132	168	36	132	16
				10″ to 18″								(Suppressed and dead only.)				
				57	14·3	26	...	75	75	95	...	259	259	...	259	25
			Total	250	27·5	53	1,611	694	2,305	116	36	391	427	36	391	42
	1915-16	62	*Pinus longifolia.*	206	33·9	64	1,662	785	2,447	32	77	200	277	113	591	70

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*PINUS KHASYA.*

Khasi and Jaintia Hills Division, Western Circle, Assam.

Locality.	Number of trees per acre.			Basal area per acre (square feet).			Mean girth (inches).			Volume per acre (cubic feet).		
	1907	1911	1914	1907	1911	1914	1907	1911	1914	1907	1911	1914
Riat Laban Sample Plot (near Pillar No. 2).	367	339	326	85·5	92·6	102·6	23·2	25·1	27·0	2,282	2,779	3,576
Upper Shillong Sample Plot in Compartment 3.	821	682	622	140·3	147·9	152·2	23·1	27·8	29·9	3,209	3,703	4,165
		1910	1914		1910	1914		1910	1914		1910	1914
Upper Sample Plot of Riat Khwan Reserve (Plot No. 11).	...	220	198	...	122·4	124·9	...	35·8	38·1	...	4,112	5,006
Lower Sample Plot of Riat Khwan Reserve (Plot No. 1).	...	176	165	...	89·1	96·0	...	34·1	36·6	...	2,573	2,605

Species—*Cedrus Deodara.*

Summary Statement from measurements of 1824 Deodar trees in Kulu Division, from the Kulu Division Research Journal lent by Divisional Forest Officer in March 1915.

Height-class (feet).	Diameter at 4½ ft.	Average length of useful bole.	Average out-turn in cubic feet.		Loss in conversion.	Form factor.		Remarks.
	Inches.	Feet.	Logs. *	Scantlings.	Percentage.	Logs.	Scantlings.	
61′—70′	24	50	80	40	50	·39	·20	86 trees measured.
	25	51	83	42	49	·37	·19	
	26	51	87	46	47	·36	·19	
	27	52	92	50	46	·36	·19	
	28	53	97	54	44	·35	·19	
	29	53	102	58	43	·34	·19	
	30	54	108	63	42	·34	·20	
	31	55	114	69	39	·33	·20	
	32	55	120	76	37	·33	·21	
	33	56	127	82	36	·33	·21	
	34	56	134	88	34	·32	·21	
	35	57	140	94	33	·32	·22	
	36	57	146	100	32	·32	·22	
	37	58	151	106	30	·31	·22	
	38	58	156	112	28	·30	·22	
	39	59	161	118	27	·30	·22	
71′—80′	24	56	76	43	43	·32	·18	253 trees measured.
	25	57	82	45	45	·32	·18	
	26	57	88	47	47	·32	·17	
	27	58	94	50	47	·32	·17	
	28	58	102	53	48	·32	·17	
	29	59	110	57	48	·32	·17	
	30	59	118	61	48	·32	·17	
	31	60	126	65	48	·32	·17	
	32	60	134	69	49	·32	·16	
	33	61	143	73	49	·32	·16	
	34	61	152	77	49	·32	·16	
	35	62	163	82	50	·32	·16	
	36	62	174	87	50	·32	·16	
	37	62	185	92	50	·33	·16	
	38	63	195	97	50	·33	·16	
	39	63	206	101	51	·33	·16	
	40	64	217	105	52	·33	·16	
	41	64	232	110	53	·34	·16	
	42	65	247	115	53	·34	·16	
	43	65	259	120	54	·34	·16	
	44	66	275	125	55	·35	·16	
	45	66	290	131	55	·35	·16	
	46	67	307	137	55	·35	·16	
	47	67	325	144	56	·36	·16	
	48	68	345	155	55	·37	·16	
	49	68	365	170	53	·37	·17	
	50	69	385	185	52	·38	·18	
	51	69	405	205	49	·38	·19	

* $\left(\frac{\text{Girth}}{4}\right)^2 \times$ length ; mid-girth taken over bark.

Summary Statement from measurements of 1824 Deodar trees, etc.—contd.

Height-class (feet).	Diameter at 4½ feet.	Average length of useful bole.	Average out-turn in cubic feet.		Loss in conversion.	Form factor.		Remarks.
	Inches.	Feet.	Logs.	Scantlings.	Percentage.	Logs.	Scantlings.	
81′—90′	24	63	78	43	45	·29	·16	405 trees measured.
	25	64	85	48	44	·29	·16	
	26	64	94	51	46	·30	·16	
	27	65	104	54	48	·31	·16	
	28	65	113	57	50	·31	·16	
	29	66	122	61	50	·31	·16	
	30	66	131	65	50	·31	·16	
	31	67	140	69	50	·31	·15	
	32	67	149	73	51	·31	·15	
	33	68	157	77	51	·31	·15	
	34	68	165	81	51	·31	·15	
	35	69	175	85	51	·31	·15	
	36	69	185	90	51	·31	·15	
	37	69	195	96	51	·31	·15	
	38	70	207	102	51	·31	·15	
	39	70	220	110	50	·31	·16	
	40	80	230	118	49	·31	·16	
91′—100′	24	70	90	53	41	·30	·18	487 trees measured.
	25	70	98	53	46	·30	·17	
	26	71	105	57	46	·30	·16	
	27	71	112	60	46	·30	·16	
	28	72	122	63	48	·30	·16	
	29	73	130	66	49	·30	·15	
	30	73	140	69	51	·30	·15	
	31	74	150	73	51	·30	·15	
	32	75	160	78	51	·30	·15	
	33	75	169	83	51	·30	·15	
	34	76	178	88	51	·30	·15	
	35	76	187	93	50	·29	·15	
	36	77	196	100	49	·29	·15	
	37	77	205	106	48	·29	·15	
	38	73	213	113	47	·28	·15	
	39	78	221	122	45	·28	·15	
	40	79	229	132	42	·28	·16	
	41	80	237	140	41	·27	·16	
	42	80	246	148	40	·27	·16	
	43	81	255	156	39	·27	·16	
	44	81	263	164	38	·26	·16	
	45	82	270	172	36	·26	·16	
101′—110′	24	74	100	54	46	·30	·16	320 trees measured.
	25	75	110	58	47	·31	·16	
	26	76	120	62	48	·31	·16	
	27	77	129	65	50	·31	·16	
	28	78	138	68	51	·31	·15	
	29	78	146	72	51	·30	·15	
	30	79	154	75	51	·30	·15	
	31	79	162	80	51	·29	·15	
	32	80	170	85	50	·29	·14	

Summary Statement from measurements of 1824 Deodar trees, etc.—contd.

Height-class (feet).	Diameter at $4\frac{1}{2}$ feet. Inches.	Average length of useful bole. Feet.	Average out-turn in cubic feet. Logs.	Average out-turn in cubic feet. Scantlings.	Loss in conversion. Percentage.	Form factor. Logs.	Form factor. Scantlings.	Remarks.
	33	80	176	90	49	·28	·14	
	34	81	182	95	48	·27	·14	
	35	81	188	100	47	·27	·14	
	36	82	194	105	46	·26	·14	
	37	82	200	110	45	·26	·14	
	38	83	205	115	44	·25	·14	
	39	84	210	120	48	·24	·14	
	40	84	215	127	41	·23	·14	
	41	85	220	133	40	·23	·14	
	42	85	225	138	39	·22	·14	
	43	86	230	144	37	·22	·14	
	44	86	235	150	36	·21	·14	
	45	87	240	158	34	·21	·14	
111′—120′	24	84	110	60	45	·30	·17	185 trees measured.
	25	85	120	65	46	·31	·17	
	26	86	130	70	46	·31	·16	
	27	87	138	75	46	·30	·16	
	28	88	146	80	45	·30	·16	
	29	88	155	85	45	·29	·16	
	30	89	164	88	46	·29	·16	
	31	90	173	91	47	·29	·15	
	32	91	181	95	47	·28	·15	
	33	91	189	99	47	·28	·14	
	34	92	197	103	48	·27	·14	
	35	93	205	107	48	·27	·14	
	36	93	213	112	47	·26	·14	
	37	94	222	118	47	·26	.14	
	38	95	233	126	46	·26	·14	
	39	95	246	138	44	·26	·14	
	40	96	260	148	43	·26	·15	
	41	97	273	158	42	·26	·15	
	42	97	284	167	41	·26	·15	
	43	98	295	175	41	·25	·15	
121′—130′	24	90	125	65	48	·32	·17	69 trees measured.
	25	91	145	70	52	·34	·16	
	26	92	160	76	52	·35	·16	
	27	93	175	82	53	·35	·16	
	28	93	184	89	52	·34	·17	
	29	94	193	96	50	·34	·17	
	30	95	200	103	48	·33	·17	
	31	95	207	109	47	·32	·17	
	32	96	213	115	46	·31	·16	
	33	96	217	121	44	·29	·16	
	34	97	221	127	43	·28	·16	
	35	97	225	132	41	·27	·16	
	36	98	229	137	40	·26	·16	
	37	98	233	142	39	·25	·15	

Summary Statement from measurements of 1824 Deodar trees, etc.—concld.

Height-class (feet).	Diameter at 4½ feet. Inches.	Average length of useful bole. Feet.	AVERAGE OUT-TURN IN CUBIC FEET. Logs.	Scant-lings.	Loss in conversion. Percent-age.	FORM FACTOR. Logs.	Scant-lings.	REMARKS.
	38	99	237	146	38	·24	·15	
	39	99	241	150	38	·23	·14	
	40	100	245	155	37	·22	·14	
	41	100	248	160	35	·22	·14	
	42	101	251	164	35	·21	·14	
	43	101	254	168	34	·20	·13	
	44	101	257	172	33	·19	·13	
	45	102	260	175	33	·19	·13	
131′—140′	24	94	155	70	55	·36	·16	19 trees measured.
	25	95	170	80	53	·37	·17	
	26	97	180	88	51	·36	·18	
	27	98	190	95	50	·35	·18	
	28	100	198	102	48	·34	·18	
	29	101	206	108	48	·33	·17	
	30	102	213	114	46	·32	·17	
	31	104	223	120	46	·32	·17	
	32	105	232	125	46	·31	·17	
	33	106	240	130	46	·30	·17	
	34	107	246	135	45	·29	·16	
	35	108	251	140	44	·28	·16	
	36	110	256	144	44	·27	·15	
	37	111	262	148	44	·26	·15	
	38	112	268	152	43	·25	·14	
	39	113	275	156	43	·25	·14	
	40	114	281	160	42	·24	·14	

Kulu Yield Table for Deodar, prepared by C. G. Trevor.

(Based on measurements of 7,700 trees.)

Diameter class (inches).	Quality I Height over 120 feet.		Quality II Height 90 ft. to 120 ft.		Quality III Height under 90 feet.		Kulu Average.		Volume of trees ado ed for calculation of the yield.	
	Logs c. ft.	Scant-lings. c. ft.	Logs c. ft.	Scant-lings c. ft.	Logs c. ft.	Scant-lings c. ft.	Logs c. ft.	Scant-lings c. ft.	1" classes c. feet.	3" classe
24	140	68	100	56	78	42	87	49	85	
25	158	75	109	59	83	45	96	54	95	95 c. ft.
26	170	82	118	63	90	48	107	58	105	
27	183	89	123	67	97	51	116	64	115	
28	191	96	135	70	104	55	127	70	125	125 c. ft.
29	200	102	144	74	111	59	136	75	135	
30	207	109	153	77	119	63	147	81	145	
31	215	115	162	81	127	68	158	88	155	157 c. ft.
32	223	120	170	86	134	72	172	95	170	
33	229	126	178	91	142	77	185	103	185	
34	234	131	186	95	150	82	198	110	200	198 c. ft.
35	238	136	192	100	159	87	210	117	210	
36	243	141	201	106	168	92	224	125	225	
37	248	145	209	111	177	98	236	133	235	237 c. ft.
38	253	149	217	118	186	104	248	140	250	
39	258	153	226	127	196	110	256	150	260 *	260 c. ft.
								*For	39" and over.	

Note.—(i) Quality I over 120 ft. height.
II from 90 ft. to 120 ft.
III under 90 ft.

(ii) Volume of logs all exploitable produce, and may therefore be used as volume of trees.

(iii) Kulu average based on measurements of 7,700 Kulu trees exploited during last 20 years.

(iv) Enumeration figures converted into volume according to figures for 3" classes. In felling against prescribed yield volume according to 1" classes will be taken.

(v) Standard loss in converting logs into scantlings: 45 per cent.

(vi) The Kulu average combines all the quality classes, and is for local application only. It is to be u only for calculating the yield and money value of the outturn over a term of years and not for one pa cular forest. For this the yield according to quality should be used.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.

ERRATUM SLIP

to

A Note on Thitsi, Melanorrhœa usitata, *Wall., with special reference to the Oleo-resin obtained from it,* by E. Benskin and A. Rodger (*Indian Forest Record, Volume VI, Part III, 1917*).

Page 15, last two lines, and page 16, first two lines, *for* " The principles and conditions of the use of Burmese and Japanese varnishes being the same, the author (E. Benskin) makes a number of suggestions for improving the Burmese lacquer industry which are given below :—" *read* " The principles and conditions of the use of Burmese and Japanese varnishes being the same, a number of suggestions for improving the Burmese lacquer industry have been made from time to time which are given below :—"

PREFACE.

THIS Note was originally written by Mr. E. Benskin, Indian Forest Service, while acting as Assistant to the Economist at the Forest Research Institute, Dehra Dun. It was sent to me for review before being printed and was then found to be out of date and incomplete. A considerable amount of further information has been collected from Divisional Forest Officers and elsewhere, and a new map has been made, but a great deal of Mr. Benskin's original manuscript is included in the Note in its present form.

A. RODGER,
Forest Research Officer,
Burma.

MAYMYO,
Dated the 14th November 1916.

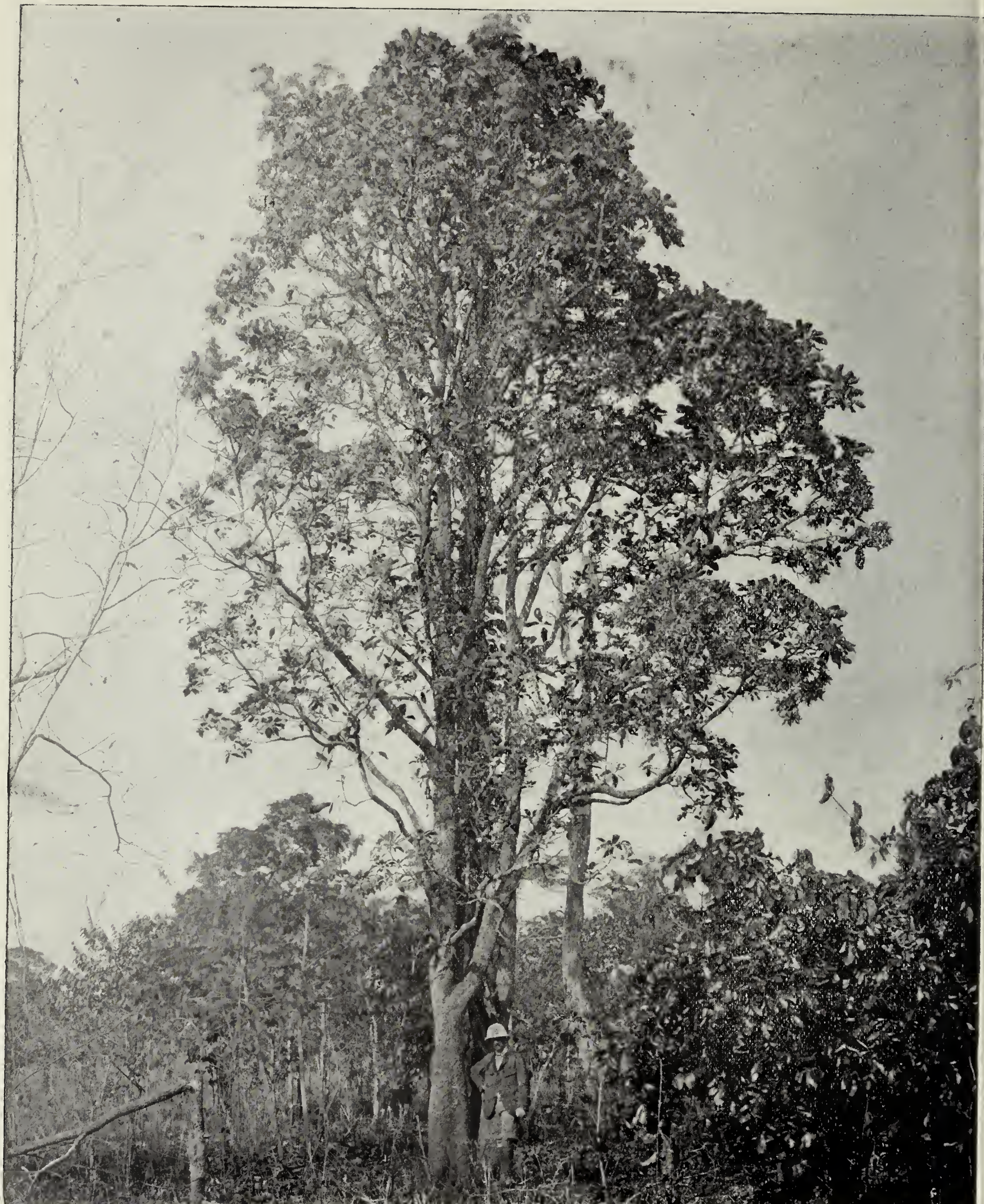


Photo.-Mechl. Dept., Thomason College, Roorkee.

Photo by A. Rodger.

Melanorrhœa usitata, Wall : in fruit and leaf.

[*Frontispiece*.

INDIAN FOREST RECORDS

Vol. VI.] 1917 [Part III.

A Note on Thitsi, *Melanorrhoea usitata*, Wall., with special reference to the Oleo-resin obtained from it.

by

E. BENSKIN AND A. RODGER, F.L.S.,

Indian Forest Service.

1. Vernacular Names.

Burmese	Thitsi.
Talaing	San.
Karen	Thu-asaw, Thu-saw, Su, Thutu, Thu (*Sgaw*), Kyoung (*Pwo*).
Kachin	Hkri.
Palaung	Gayé.
Shan	Tunhat, Maihat, Hwik, Hak, Mai-hun (*Siamese Shan*).
Taungthu	Thi *or* Si.
Chin	Ayon or Son, Lein (*Haka*), Che' (*Chinbok*), Ashadon (*Chinbon*).
Chinese	Chang.
Manipuri	Kheu.

2. Distribution and Habitat.

This tree is found in the drier forests of Burma up to about 3,500 feet, usually in the type of forests known as *Indaing*, in which the predominant tree is *Dipterocarpus tuberculatus*, Roxb. It may be seen from the map, which accompanies this note, that the forests containing the tree are frequently found on the flat land and low hills lying between the main rivers and the main ranges of hills. It does not occur wild in Burma, north of latitude 25° and south of latitude 15°, and has not been found in Arakan. In the following table the estimated areas, in square miles, on which the tree occurs in each forest division in Burma are given.

Thitsi-bearing areas, in the various Divisions of Burma, in square miles.

Circle.	Division.	*Thitsi* plentiful.	*Thitsi* not plentiful.
Pegu	Thayetmyo	100	230
	Prome	35	118
	Zigôn	4	20
	Tharrawaddy	..	10
	Insein	..	..
	Henzada	..	30
	Bassein	..	..
	Arakan	..	..
TOTAL	..	139	408
Tenasserim	North Toungoo	39	134
	South Toungoo	17	31
	Shwegyin	56	55
	Nyaunglèbin	..	..
	Pegu	..	..
	West Salween	86	241
	Thaungyin	3	47
	Ataran	9	2
	South Tenasserim	..	..
TOTAL	..	210	510
Northern	Bhamo	..	5
	Myitkyina	..	10
	Katha	490	245
	Mu	1,224	1,404
	Upper Chindwin	150	25
	Mansi	..	..
	Myittha	148	282
	Lower Chindwin	30	35
TOTAL	..	2,042	2,006
Southern	Ruby Mines	400	1,000
	Mandalay	88	96
	Meiktila	132	478
	Pyinmana	10	17
	Southern Shan States	2,550	2,200
	Yaw	2	5
	Minbu	18	5
TOTAL	..	3,200	3,801
GRAND TOTAL	..	5,591	6,725

It usually occurs in association with the following, besides *Diptero-carpus tuberculatus* Roxb.: *Dillenia pulcherrima*, Kurz., *Shorea obtusa*, Wall., *Pentacme suavis*, A. DC., *Lophopetalum Wallichii*, Kurz., *Buchanania latifolia*, Roxb., and many others which thrive on sandy, laterite, and the drier soils. The undergrowth often consists of *Indigofera pulchella*, Roxb., *Phœnix acaulis*, Buch., *Blinkworthia lycioides*, Choisy., *Flemingia* sp., *Cycas siamensis*, Miq., and similar shrubs. Mr. Marsden estimates that there may be an average of 8 trees to the acre in favourable localities, but it is often found scattered in small numbers over very large areas of forest. In the Katha Division, Mr. Blanford puts down the average proportion of *thitsi* as between 1 in 50 to 1 in 100 of other species. In the hills, it is smaller in size and is usually found with oaks such as *Quercus serrata*, Thunb., *Q. Lindleyana*, Wall., *Q. fenestrata*, Roxb. and with *Schima Wallichii*, Choisy.

Mr. Copeland in his "Manual of Arboriculture for Burma" says that the tree prefers a gravelly soil, and is therefore recommended for localities in the dry zone where the soil is not too clayey.

It is very abundant in some parts of the Southern Shan States, and often forms half the growing stock of those zones of forests in which the oak is merging into *Shorea obtusa* forest.

Mr. Blanford says that the Burmans consider that there are three kinds of *thitsi* trees: the black, the red and the white. The three varieties differ only very slightly. The red and white varieties are, to all intents and purposes, indistinguishable. The black has a slightly darker brown bark and slightly rounder leaves, and can, with a little difficulty, be distinguished from the other two kinds. The question of difference is not one of locality, as all three varieties are found on the same locality, though usually where the trees are at all numerous several trees of one variety form groups. The chief difference between black and other varieties appears to be in the outturn of the oleo-resin, as the black variety produces by far the most oil.

The oils produced by the black and red varieties differ slightly in colour, but the superiority of the commercial red *thitsi* oil is chiefly due to other causes.

To the west, the tree is found in Manipur but is not known to exist in Assam. Mr. Perrée says that he thinks that in the Manipur State *thitsi* or *khew* is confined to the regions of the Burma border where the *Indaing* type of forests occur.

This opinion is confirmed by a former Political Agent, Lieutenant-Colonel J. Shakespear, C. I. E., D.S.O., who states that the tree is found only on the lower slopes of the hills, on the west of the Kabaw valley, and that its occurrence is rare.

3. Description of the Tree and Timber.

Melanorrhœa usitata, on suitable soils, attains to a very considerable size. In most parts of Burma a tree 50 to 60 feet high, with a girth of 9 feet at breast-height, would be considered large.

Mr. Blanford, Divisional Forest Officer, Katha (1911), says :—"The usual size to which *thitsi* trees grow in this Division would appear to be about 7 feet breast-girth, but the Sub-Divisional Forest Officer, Tigyaing, considers that 10 feet would be the average figure in the better localities, and himself measured one tree of 14 feet 6 inches. This must, however, be considered exceptional." The bark is dark-grey, irregularly breaking up into small angular scales.

The tree sheds its foliage about January, during which period it flowers, and the leaves reappear in the middle of March, but these dates are later in the hills. The parachute-like fruits become fully ripe and drop during the months March to June. Just before the leaves appear the tree is often covered with the fruits, each of which is supported by several long, bright red, spreading, enlarged petals. The mass of colour thus provided is very striking (see Frontispiece Plate I). The trees are usually straight, clear-boled up to a fair height and cylindrical, having a large spreading crown with simple, dark-green leaves. In January the tree, when in blossom, is a pretty sight ; the flowers are individually small, but the mass of panicle inflorescences gives it a spangled, starry appearance : the flowers are white, and the mass has a very light yellow appearance.

Owing to the fact that it has a large spreading crown, it makes a good shade tree for roads in dry gravelly places.

The timber is dark red, very hard and durable, and has a handsome appearance ; it is strong, and is used for buildings, bridges, ploughs, tool-handles, anchor-stocks and turning.

4. Natural and Artificial Regeneration.

Seed years are irregular, but good seed may usually be obtained every few years and, in a favourable season, numerous seedlings may be found at the beginning of the rains in the more open parts of *Indaing* forests. The growth of the young plants is not rapid, the height of seedlings in a nursery, in the rains of 1916, being not more than four inches, five months after sowing.

Mr. Marsden recommends that the seeds should be collected as soon as possible after falling to the ground, then kept moist in heaps to encourage germination, and the germinated seed sown. The young

Photo.-Mechl. Dept., Thomason College, Roorkee. Photo by J. D. Clifford.

Tapping of *Thitsi* trees in Pyinmana forests, Upper Burma.

[*To face page 5.*

plants require watering and care at the start; and, even with great care, the percentage of failures is extremely high.

Mr. Copeland in his " Manual of Arboriculture " says :—" The seeds should be collected as they fall (just before the rains), and sown at once as they soon lose their germinating power. They may be sown at site, two or three seeds in each pit. When about a month old, the weaker seedlings should be plucked up by the roots, leaving only the most vigorous ones to grow up. Or the plants may be raised in baskets and planted out when large enough—probably when about 18 months old. In dry localities, they will require to be watered for the first hot season after being put out. The trees should be placed 30 feet apart along roadsides."

5. Method of tapping the trees.

Mr. Blanford, Divisional Forest Officer, Katha (1911), gives the following interesting account of the method of tapping the tree to obtain the oleo-resin :—

Time of collection.—" The oil can only be collected from June to January, *i.e.*, while the sap is flowing."

Method of tapping.—" The usual method of tapping is to make two deep notches to form a V. The notches are 8 to 10 inches long, and about two inches deep. At the base of the V, small bamboo cups are placed, with an edge stuck into a small horizontal cut just at the base of the V, in such a way that the oil which exudes from the V-shaped notch flows into the cup (see Plate II). The oil can only be collected in fairly dry weather, as when it rains the oil is either washed away or is too diluted in the cups to be of any use. If only a little rain-water is mixed with the *thitsi*, it becomes of a reddish colour. The number of cups that can be put on one tree depends on the size of the tree, and whether the tree is to be tapped for a large temporary outturn or for a regular yearly outturn. It is usual to have notches, one above the other, as high as a man can reach. About 4 or 5 can be made in a slanting direction, one above the other. Once the tree has been tapped in any one place, it must be left at least 4, if not 5, years to allow the original notches to heal over completely before being tapped again.

" It thus follows that, if a line of notches is made each year and the tree is big enough to allow of 5 lines being made, the tree can be tapped every year; for, as soon as the total available surface has been tapped, the old blazes will have healed up completely and notching can be continued. The notching appears to have no effect on the life of a tree, and trees that are covered with scars appear to be as healthy as those which have not been tapped. Trees of all sizes can be tapped, but of course

only trees of some size (about 6 feet breast-girth) can be tapped every year for the reasons specified above."

During the months of March and April, the oleo-resin does not flow readily, so that the tapping must be confined to the months specified in the above account. Sir D. Brandis gives the following account of the method used in the Shan States, taken from Watt's "Dictionary of the Economic Products of India":—

"The trees which have been tapped are at once known by triangular scars about 9 inches long, and 5 inches broad, the apex pointing downwards. On some trees we counted 40-50 of these scars, and some of them at a height of 30 feet. To work the higher scars, the Shans use a most ingenious ladder which is permanently attached to the trees. It consists of a long upright bamboo, with holes cut through at intervals of 2-3 feet. Through each hole are passed two flat bamboo sticks driven with their pointed ends into the bark. These form the spokes of the ladder and are about 12 inches long. The scars or notches, to extract the varnish, are made with a peculiarly shaped chisel about 15 inches long; the handle is of iron, of one piece with the chisel and about 9 inches long; the lower end thicker, hollow, and closed with a bamboo plug. The chisel is wedge-shaped, about 6 inches long (the edge half an inch broad), and forms an obtuse angle with the handle.

"With this instrument two slanting slits, meeting at an acute angle, are made upwards through the bark, and the triangular piece of bark between the two slits is thus slightly lifted up, but not removed. A short bamboo tube about 6 inches long, with a slanting mouth and a sharpened edge, is then horizontally driven into the bark below the point where the two slits meet, and the black varnish which exudes from the inner bark, near its contact with the wood, runs down into the bamboo tube, which is emptied at the end of 10 days, when it ceases to flow. A second cut is then made so as to shorten the triangular piece of bark which has been separated from the wood when the first cut was made. A shorter triangular piece of bark remains, ending in an angle less acute than before. The bamboo tube is then removed a little higher, and the edges of the original cut are cut afresh.

"The varnish then runs out for another ten days, after which the scar is abandoned. The trees vary in yield exceedingly; a crooked tree, with scanty foliage, which we examined was said to yield a good outturn, while some of the largest trees were said to yield very little. We saw trees tapped which has a diameter of only 9 inches. Moungmyat informed us that one man could make and look after 1,200 scars: that he could do 200 in a day, so that the whole number occupied 6 days,

which left 4 days for rest. They only work in those parts of the forest where the tree is abundant and trees fit to tap stand closer together.

"The tree yields nothing while it is leafless in the hot season, and the best season for working is from July to October. One man collects 40-50 viss (146 to 182 lbs.) in one season; at Tyemyouk the viss sells for 12 annas, and at Rangoon for one rupee."

The *thitsi* tree is closely allied to the Japanese lacquer tree *Rhus vernicifera*, and it may be of interest to note here that the Japanese consider that the sap obtained from the lower part of the tree is superior to that obtained from the higher parts of the trunk.

The varnish exudes from the tree as a thick greyish fluid which turns brown, and then jet black on exposure to air. Great care should be taken in handling the substance as it is liable to cause inflammatory swellings on the exposed parts of the body. It is said that some people will not cut or tap the tree on this account, while on others it has no effect. This poisonous property is stated to be due to a volatile oil, against which an infusion of teak wood is recommended. The writer (E. Benskin) in experimenting with this substance at the Forest Research Institute at Dehra Dun suffered considerably from those swellings but found that the varnish, when adulterated with ferric oxide up to 10 per cent. of its weight, has apparently no effect on the skin, and the addition of this mineral considerably increases the drying capacity of the varnish. Mr. Puran Singh suggests that, to get rid of this poisonous substance, the oleo-resin should be stirred in the open in shallow vessels.

Most writers testify to the wanton damage that is being done to the trees by over-tapping. Steps should therefore be taken to regulate the tapping, as unless this is done, a sustained annual yield may become impossible in the near future. Such regulations should limit the minimum size of the trees to be tapped, the number of blazes that should be made on trees of different girth, and trees which have been tapped should be allowed to rest for a number of years in order to recover from any damage resulting from tapping. Forest officers in Burma, however, are not all agreed as to the minimum size that should be tapped, and it would be useful if experiments were made to determine the girth at which trees can be tapped without seriously interfering with their growth and productivity.

6. Uses of the Oleo-resin.

Although the timber of *Melanorrhœa usitata* is not at present used to any great extent, the tree is highly prized by the Burmese on account of the oleo-resin or so-called varnish which exudes from the trunk when

wounded. This oleo-resin can be used pure or adulterated as a thick coating of black varnish which can be applied both to outdoor and indoor structures ; the wood so treated is stated to become proof against termites and fungi, due presumably to the extremely hard surface of the varnish when dry. It is used for caulking boats and as a non-fouling paint ; it is also reported to preserve wood from teredo attack for twenty years. An experiment is now being carried out to see whether timber so treated is really proof against attack. Its chief use is for Burmese lacquer work, of which it forms the principal constituent. The lacquer work of Burma is well known, and lacquered articles are found in nearly every household of that country. The articles now made are usually betel-boxes, cups, trays, small tables, boxes, vessels for monks' food, etc., and articles such as cigar-cases and walking-sticks are made for sale to Europeans.

Thitsi, again, is used as a coating upon surface intended to be gilded with gold-leaf. " For this it would seem to be not only a valuable, but also an indispensable, commodity in a country abounding, as Burma does, in temples, pagodas, shrines, and monasteries. The spires, minarets, facades, and decorations of these and other sacred structures are frequently completely gilded with gold-leaf.

" Among the less known of the special uses to which the oleo-resin is applied in Burma is the embossing of the enamel-like ornamental letters that adorn the exquisite palm-leaf Pali boxes of the religious Orders of the country. Again, for the delicate ornamentation of the borders of the head-dress and the hem of the folded robe of the Buddha, as delineated in the beautiful alabaster figures of that great " Giver of Light and Life " the oleo-resin is largely requisitioned." (*A. M. S. in Capital, 5-3-08.*)

Interest in the Chinese and Japanese lacquer varnish, obtained from the tree *Rhus vernicifera*, was aroused in Europe fully two hundred years ago, but it was not until half a century after this that attempts were made to ascertain the source of Siamese or Burmese varnish, which was considered to be inferior to that obtained from China and Japan.

The discovery of the varnish tree of the Burmese by Dr. Wallich is referred to in the Asiatic Journal, Volume 25 of 1828, page 454.

Although this varnish is so well known in Burma, yet it is practically unknown in Europe, as its use has hitherto been restricted to a special class of work.

Various attempts have, however, been made during the last two years to introduce it on the European market. The success has not been great, but the substance of a report received from the Director, Imperial Institute, London, is given below :—

" A second firm reported that they considered the material to be

Photo.-Mechl. Dept., Thomason College, Roorkee.

Pagan lacquer ware : showing the various stages in the manufacture.

[*To face page 9*

much like Japanese varnish, derived from *Rhus vernicifera*, but devoid of the acrid and irritant properties of the latter. They found that a coat of *thitsi* was extremely resistant to strong alkalies and acids, and that even when exposed for a time to the action of water it remained practically unaffected. For the drying of *thitsi* the conditions required are similar to those required for the Japanese varnish, *i. e.*, it must be left in a cool, damp place and not in dry air or light."

Other reports from varnish makers, waterproof manufacturers, patent leather firms and numerous other experts are, on the whole, not encouraging, the length of time necessary for drying being the usual cause of complaint.

7. Lacquer Work of Burma.

As has already been stated, *thitsi* is the principal constituent of the Burmese lacquer varnish. Mr. H. L. Tilly in his book on "Glass Mosaics of Burma" (1901) says that the lacquer art is not indigeneous to Burma, but was introduced from Siam after an invasion of that country by Naungdawpaya, son of Alaungpaya, and, to this day, some of the best masters are Shans.

A detailed account of the method employed in lacquering different articles is given in the Royal Botanic Gardens, Kew, Bulletin of Miscellaneous Information, No. 5 of 1906, entitled "Burmese Lacquer Ware and Burmese Varnish", by Sir George Watt.

The following descriptions of all except Pagan work are chiefly taken from this publication, and also from information available in the records of the Forest Research Institute. Mr. A. P. Morris, Provincial Art Officer, Burma, has also kindly supplied a good deal of information.

The following are the principal kinds of lacquer ware now made :—

Pagan lacquer ware.	Mandalay moulded work.
Gilt lacquer ware.	Burmese mosaic work.

Manipur varnished wares.

(1) *Pagan lacquer ware.*

For the foundation of these lacquered articles wood, bamboo, or cloth is used. Thin planks of the soft white wood of Baing (*Tetrameles nudiflora*, R. Br.) and Didu (*Bombax insigne*, Wall.) are used for large boxes, dishes for the food of Buddhist monks, trays and small tables, and cloth is used for cigar-cases. For betel-boxes, cups, etc., Tinwa (*Cephalostachyum pergracile*, Munro.) is nearly always employed

as the other bamboos are too hard. From this bamboo long, thin strips are cut off between the nodes, the central portion only being used, as the inner and outer layers are too hard. These *hni-laung* are boiled in water for about a day, and may, on the following day, be split up into the thinner strips which form the foundation of the article to be made. The Burmese cup shown in Plate III may be taken as an example. A wooden mould, of the size and shape of the cup to be made, is taken, and on the base of this are placed crosswise 4, or in the case of large articles 5, thin strips of the split bamboo, and the basket work is woven with these as a foundation, from the middle outwards, thin narrower strips of bamboo being employed for this work. After an inch or two of this close work has been finished, other thin flat strips are woven in to strengthen the walls of the cup, the total number of these flat strips being, for large articles, as many as 20. When the bottom is finished, the strips are turned over and the walls continued on the mould, and when these have been carried to the required height, the top and bottom edges of the small basket thus obtained are finished off with narrow slips of bamboo. A thin coating of *thitsi* is then given to the basket, which is put in the sun, and then into an underground cellar for five days. The mould with the basket on it is then placed on a rough lathe, and a second coat of *thitsi* forced into the fabric, while it is being turned, by means of a tool with a turned-over blade called a *thangyeik* (see Plate IV). A coating of fine red sand is then given, then another coat of *thitsi*, then *thitsi* and finely powdered cowdung, then *thitsi* and paddy husk. The cup is constantly turned and treated inside and out, and rubbed with cloth and the fingers, until the whole cup has received a hard dull rough-looking coat. It has now been prepared for its coating of good *thitsi*, which forms the base of the lacquer work. This is usually applied 5 times, several days often elapsing between the applications. The *thitsi* is well rubbed in on the lathe, the cup is then put in the sun, and is later put in the underground cellar. After this has been done a number of times, the cup is covered with a hard, black, shining coat, but the process may take as long as a month. For cheaper wares, fewer coats of *thitsi* are given, but the constant placing of the article in the cellar is required to ensure that a well-dried and thoroughly hardened coat may be obtained. The artist, who is responsible for the main design, is now called in, and draws this on the hard surface, with a long pointed steel style, without preparation or guide lines of any kind. A paste is made of 10 parts by weight of *thitsi*, 10 parts of vermilion finely powdered, and $2\frac{1}{2}$ parts of *shansi* (a vegetable oil obtained from the Shan States). This is thoroughly rubbed into the design three times, with an interval of several days between each application, the box being put in the sun and in the cellar where

Photo.-Mechl. Dept., Thomason College, Roorkee. Photo by A. Rodger.

Lacquer Workers at Pagan.

[*To face page 10.*

the *thitsi* will cool and harden slowly after each application. When the design is fixed the surface is polished with paddy husk and water and a soft cloth. The other colours usually used are green, and light and dark yellow. The light yellow powder is finely ground sulphur, and the dark yellow is made by adding to it a little vermilion: green is made from the vermilion and indigo. The details of the design required in green and yellow are made in each case by scratching the surface with the steel style and rubbing in the required powder, and for the intricate designs that the more expensive articles bear the process is long and complicated, the article being in each case kept in the cellar for one or more days, so that the *thitsi* may become thoroughly hardened. The original shining black *thitsi* remains as the back-ground, which is often almost entirely hidden by the red, green, and yellow of the ornamentation.

A thorough polishing is given to the cup with paddy husk, finely powdered charcoal and soft cloths, the result being that all the superfluous colour is removed and the whole surface brought to a smooth finish on which the design shows clearly. These complicated operations may last, in the case of a large box or tray, for as much as one year, from first to last. The result is not always pleasing to the European eye, as there seems to be an unnecessary mass of detail, and the colours are often crude, but the neatness of the workmanship and the great skill necessary to construct well-made articles out of such flimsy materials, will always command admiration. The products, especially betel-boxes, are sold throughout the length and breadth of Burma and are in universal use. The work is carried out by villagers under the superintendence of the headman or headwoman of the business, each worker doing one particular part and being paid by the piece. Burmese girls are extremely neat-handed and do all the weaving of the bamboo baskets, being paid about Re. 1 per hundred for small betel-boxes. The art is an important means of livelihood in several places in the Myingyan district of Upper Burma.

(2) *Gilt lacquer ware.*

As in the Pagan ware, the articles to be adorned go through a series of preliminary preparations so as to obtain one even surface on which the gold leaf design can be applied.

After the lacquered articles have been thoroughly smoothed down, a coat of *thitsi* is applied, either plain or mixed, with a small preparation of *hinthapada* (vermilion) which gives a red colour. The articles are then placed in an underground cellar for a day or two.

When the *thitsi* has sufficiently hardened, but before it is quite dry, the craftsman proceeds to paint the design on the box, basket, table or whatever is to be ornamented. The paint used is made from finely powdered sulphide of arsenic moistened with water, to which a little gum arabic has been added to make it adhere to the *thitsi*. The design thus painted is the negative of the design, only those parts being painted where no gilding is required. This outline must be finished before the *thitsi* is dry. Gold leaf is then applied to this surface and adheres all over, but on working with water the gilding comes away with the arsenic paint, leaving in these parts the original glossy black, or red, background.

Prome used to be the most noted place for this work, but the trade is no longer carried on there. There are skilled craftsmen at Pagan and Mandalay, and in one or two other places.

3. Mandalay moulded and ornamental ware.

Perhaps one of the most interesting arts in which *thitsi* is employed can be seen in Mandalay where articles are lacquered not only in the Pagan style already referred to, but are, in addition, embossed with moulded work, elaborated in rich scrolls and grotesque animals and other floral and animal designs.

For the moulded work the oleo-resin is thickened with carefully prepared rice husk or cowdung ashes until it attains the consistency of putty, the composition of this putty being two parts of *thitsi* to one of foreign matter. A flat stone or board, carefully dusted over with fine ashes, is used as the moulding table. The *thitsi* is then moulded to the required shape with the hands, which are kept greased with oil to prevent the putty adhering to the fingers. The only tool used by the craftsman in shaping his putty is a small curved knife of buffalo-horn. The shaping of the main outlines and the cutting of deep lines to represent the veins of foliage is done with this instrument, but the delicate leaves and curving tendrils are formed by the deft fingers of the caftsman. When finished, each small piece is lifted from the moulding board and transformed to a surface freshly painted with *thitsi* to which it adheres. It is then varnished once with a thin coat of the best *thitsi* and put in a cellar to dry. In this way foliage, animals, human beings and mythical figures are represented with extraordinary delicacy, but it is in foliage that the craftsman especially excels.

The designs include certain patterns standardized by custom and recognised as readily as any classic order at home. The determining feature in a design is, however, not the type, as we might speak of an

Acanthus leaf pattern, but the general outline. Provided the craftsman keeps to the outline, the actual shape of the leaves may vary considerably.

In many cases the designs are richly ornamented with gems, mica and glass of all colours, imbedded in the soft *thitsi* putty.

This art is largely used for the ornamentation of fancy boxes, thrones, idols, and stands on which coffins are deposited; in fact, for every description of work where an elaborate design is required. The same material and method is often adopted in the ornamentation of the many-trayed baskets in which Burmese ladies store their treasures and jewels; the foundation of these baskets is generally a wicker work basket, made, as already described, in connection with the Pagan ware.

4. *Burmese glass mosaics.*

The art of wall decoration, by means of coloured glasses imbedded in a layer of *thitsi*, came to Burma from Siam: such decoration can be seen in the Shwedagon and other pagodas in Burma. Mr. Sitzler, I. F. S., has kindly given the following account of the glass mosaics in the Shwedagon pagoda at Rangoon:—

"The Shwedagon pagoda consists of a lofty bell-shaped brick-built pyramid, overlaid with gold, ascending to a height of 370 feet above the massive mound on which it is built. Around the base are a large number of shrines roofed with towering pinnacles, which are ornamented with wood carving and gilding, and are often supported in round columns overlaid with mosaics and gold leaf, while the richly carved capitals of these may be gilded. Reclining images of Buddha, overlaid with gold, either alone or surrounded by his disciples, are often set off by the finest examples of Burmese mosaic work. It is in fashioning these mosaics that *thitsi* is brought prominently into use.

"Firstly, the pillar or other part of the structure to be decorated is plastered over with *thitsi* thickened into a putty by means of ashes or some other medium. Strings of *thitsi*, made by kneading a mixture of ash and teak sawdust, are then made having a thickness of $\frac{1}{4}''$ to $\frac{3}{8}''$.

"These strings are decoratively laid, in the form of flowers and other fantastic designs, over the pillars, which have been well plastered with *thitsi*, and adhere strongly. After this, generally on the next day, the whole pillar, with its embellishments, is covered over with a second layer of *thitsi*. While the layer is drying, *i.e.*, an hour or two after the application, the outlines of the flowers and tracing formed by the artist are laid over with gold leaf, and in the interstices left in the gilded tracing are placed pieces of coloured glass in mosaic, which become firmly plastered to the pillar when the *thitsi* dries.

" At the foot of the pillar or plinth base and pedestal the *thitsi* is usually overlaid with vermilion or crimson paint, but often enough the base and pedestal are gilded, and the capitals are finely carved and gilded."

A very detailed account of the " Glass Mosaics of Burma " is given by Mr. Tilly in his interesting note which contains many excellent photographs, and is obtainable from the Superintendent, Government Printing, Burma, Rangoon, price Rs. 9 or 13 shillings and 6 pence.

5. *Manipur varnished wares.*

As has already been stated, the tree yielding the varnish occurs only to a very limited extent in the Manipur State. The lacquer art is practically unknown there, and the varnish is merely used for ordinary domestic purposes and at the present time is rarely met with.

6. *Other lacquer-work.*

Besides the abovementioned types of lacquer work several others should be mentioned, the chief centres of which are in the Shwebo district, where mud images of Buddha are lacquered ; also in the Lower Chindwin district and elsewhere, certain villages manufacture plain red and black lacquer ware in considerable quantities. At Maungdaung in the Lower Chindwin the workers have recently started a Co-operative Society. In the Northern and Southern Shan States there is also a fair trade in this work ; in the Northern States we find the red lacquer ware used principally to contain religious offerings.

The chief lacquer working centre in the Southern Shan States is Laikha. There the work is crude and unfinished, but interesting because the workers are said to have learnt the work from Pagan a century or two ago and it is possible that the very rough patterns represent the work done at Pagan in old days. Generally, a red background is used by mixing *hinthapada* with the *thitsi*, and on this very crude patterns are scratched. Variety of colours is not used, and the pattern is often put in with silver paint, the surface being afterwards varnished with *kanyin-si* (wood-oil of *Dipterocarpus* sp.), which, being a yellow varnish, makes the silver appear a dull gold. The use of *kanyin-si* makes the articles unsuitable for holding hot water. The Pagan lacquer ware will stand hot water quite well.

From Laikha some while ago a group of lacquer workers moved off to Kengtung where they form a small colony. They have developed an industry of their own in the making of basket-shaped bowls ornamented either with smooth gilt work, or with work of Mandalay moulded-ware type, rather minute in detail, gilt all over, and occasionally ornamented with small pieces of coloured glass.

Although the art of making lacquer ware is not as flourishing as it was in the past, it is still the means of livelihood of some thousands of villagers, and must be regarded as one of the chief minor handicrafts of Burma. Some 7,000 people were engaged in the work in 1901.

8. Laboratory Experiments.

Thitsi has recently been the subject of a special enquiry by Mr. Puran Singh, Chemical Adviser to the Forest Research Institute, Dehra Dun, and is dealt with in *Indian Forest Records* (1909), Vol. I, Part IV, pages 287 to 308. The specific gravity at 20°C. of a pure sample was 1·0016, which is practically equal to that of the Japanese lacquer. It is of a black colour with a slight, but not unpleasant, smell.

The chief constituents of the Burmese varnish are urushic acid ($C_{14} H_{18} O_2$), which by quantitative analysis forms about 85 per cent., diastatic matter, gum, and oily matter ; the composition, therefore, of *thitsi* is identical with Japanese lacquer varnish, in all its essential characteristics. The chief defect in the Burmese varnish is its incapacity for drying ; in order, therefore, to determine the essential conditions for drying the varnish, experiments were made with the original juice and mixtures of its several constituents, and the following conclusions were obtained :—

(*i*) That it is the action of the diastatic constituent in the urushic acid which causes the hardening of the varnish ; but the diastase to display this activity, must be in its original form, as it is present in the natural varnish ; coagulation paralyses its action on the urushic acid.

(*ii*) That moisture is essential in the process of drying.

(*iii*) That the diastatic matter begins to lose its activity between 50° and 60° C. and entirely loses its activity between 60° and 65°C.

(*iv*) That adulteration with sesamum oil (*Shansi*) greatly impairs the drying power of the varnish.

The principles and conditions of the use of Burmese and Japanese varnishes being the same, the author (E. Benskin) makes a number of

suggestions for improving the Burmese lacquer industry which are given below :—

(*i*) The iron chisels used for the extraction of the varnish should be free from rust, as rust spoils the varnish by its action on the urushic acid.

(*ii*) Dust should be avoided.

(*iii*) The juice extracted from the lower parts of the Japanese tree is known to be superior to that obtained from the upper part ; the author recommends that this be followed in Burma.

(*iv*) The juice should be stirred for some hours in open, shallow vessels with a flat paddle, as is done by the Japanese lacquerer, the varnish so becoming of a more homogeneous nature and any poisonous volatile matter being evaporated.

(*v*) Iron vessels should be scrupulously avoided in making lacquer of various colours, as the rust from the iron vessels, by combination with urushic acid, makes the colour of the varnish a dull brown.

(*vi*) The air of underground cellars, where the lacquered articles are put to dry, should be kept moist by hanging wet cloths from the walls and roof.

(*vii*) Sesamum oil should be avoided as an adulterant and linseed oil should be used.

During the year (1913), the writer has been carrying out a number of experiments, with a view to improving the drying capacity of this natural varnish, and so render it more adaptable to the lacquer industry and possibly increase its utility in other directions.

With this end in view, 19 samples of *thitsi*, prepared in the manner shown in the table below, were sent to a local firm of cabinet-makers and their report as to whether they would be able to use any of the same in their work is incorporated in the remarks column. Two coats of varnish of each sample were applied to both a hard and a soft wood, and the rapidity in drying was recorded every 24 hours. It should be mentioned that the articles so varnished were left to dry indoors under usual conditions, and the weather at the time was fairly dry during a break in the rains.

After the firm had pronounced their opinion, all the specimens of the varnished woods were placed, for 3 weeks, out in the sun on a concrete floor, in order to test their durability under the ordinary weather conditions.

Results of experiments with Thitsi *when applied to a soft wood and a hard wood.*

Serial No.	Varnish how prepared.	Time taken to dry in days. 1st coat only.	REMARKS.
1	*Thitsi* + 12½ per cent. *Boswellia serrata* oil.	2 S. 3 H.	Equally suitable for soft and hard woods. Has an excellent gloss and, in appearance, is superior to all the other samples of varnish. Would make a useful thick varnish for furniture. Turns slightly brown in sun.
2	*Thitsi* + 33⅓ per cent. *Boswellia serrata* oil + 10 per cent. *Boswellia serrata* rosin.	4 S. 4 H.	Takes too long to dry, otherwise of very fair appearance. Turns quite brown in the sun.
3	*Thitsi* + 12½ per cent. *Boswellia serrata* oil + 10 per cent. *Boswellia serrata* rosin.	4 S. 4 H.	Takes too long to dry, otherwise of very fair appearance. Turns quite brown in the sun.
4	*Thitsi* + 12½ per cent. Chir turpentine.	3 S. 3 H.	Not much gloss and rather too thick; turns brown when exposed for long periods to sunlight.
5	*Thitsi* + 33⅓ per cent. Chir turpentine + 10 per cent. rosin.	3 S. 3 H.	Has a very good gloss and is very nearly as good as No. 1, but is slower in drying. Would make a useful varnish for furniture; suitable for both soft and hard woods. Turns reddish brown in the sun.
6	*Thitsi* + 12½ per cent. Chir turpentine + 10 per cent. rosin.	3 S. 3 H.	Fair appearance. Turns brown in the sun.
7	*Thitsi* + 12½ per cent. spirit and 10 per cent. shellac.	4 S. 4 H.	No use to the cabinet-maker, as it blisters. (Probably due to turpentine getting into the sample.)
8	*Thitsi* + 10 per cent. Chir rosin.	4 S. 4 H.	Takes too long to dry. Turns brown in the sun.
9	*Thitsi* + 5 per cent. Chir rosin.	3 S. 3 H.	Thick but good appearance, and would probably make a good lacquer. Slightly affected by the sun.
10	*Thitsi* + 5 per cent. gum arabic.	3 S. 3 H.	Too thick for hardwoods, of very good gloss, and would probably make a very fine lacquer. Not affected by the sun.
11	Pure *Thitsi* . . .	4 S. 4 H.	Takes too long to dry and too thick to be of use for furniture, has a good gloss. Very slightly affected by the sun.
12	*Thitsi* + 25 per cent. Ferric oxide + 25 per cent. Chir turpentine.	1½ S. 1½ H.	A quick drier but lacks gloss; would make a useful varnish. Very slightly affected by the sun.

Results of experiments with thitsi *when applied to a soft wood and a hard wood*—contd.

Serial No.	Varnish how prepared.	Time taken to dry in days. 1st coat only.	Remarks.
13	*Thitsi* + 20 per cent. Ferric oxide + 10 per cent. Chir turpentine.	1½ S. 1½ H.	A quick drier and would make a useful varnish, but not as good a gloss as Nos. 1 and 5. Not affected by the sun and the gloss improved in the sun.
14	*Thitsi* + 25 per cent. Ferric oxide + 25 per cent. *Boswellia* oil.	1½ S. 1½ H.	A good drier, and could be used; of inferior gloss to No. 13 but of very fair appearance. Unaffected by the sun.
15	*Thitsi* + 5 per cent Ferric oxide	2 S. 3 H.	Could be used but dries slower than Nos. 12, 13 and 14; has a good gloss and would probably make a good lacquer. Not affected by the sun.
16	*Thitsi* + 2 per cent. Manganese dioxide.	3 S. 4 H.	No use to the cabinet-maker.
17	*Thitsi* + 50 per cent. turpentine + 20 per cent. Ferric oxide.	1 S. 1 H.	A good varnish having a rich brown colour and very fair gloss, but is only suitable for varnishing hard woods. Keeps an excellent appearance in the sun, but colour becomes somewhat lighter.
18	*Thitsi* + 2 per cent. Formaline.	Over 10 days.	No use to the cabinet maker.
19	*Thitsi* + 5 per cent. Formaline.	Do.	Ditto.

Note.—A thick coat was applied to each specimen of wood and they were then left to dry under cover.
S. = Soft-wood.
H. = Hard-wood.

From the above table it will be seen that the firm report very favourably on samples Nos. 1, 5, 13 which, they consider, would be suitable for their work; their report, however, was given before the outdoor durability tests were carried out. It is, however, doubtful whether the effect of sunshine is of much importance, in the case of varnishes used solely for furniture and indoor decoration. The drying capacity of varnishes Nos. 1 and 5 are not good, but the splendid surface obtained to a certain extent compensates for this drawback.

Varnish No. 13 (containing ferric oxide as a drying agent), which the firm considered the third best for their purposes, is a quick drier; and as the action of the sun does not affect the colour in any way, it would probably be superior to the other two samples.

Whether the effect of sun would really depreciate the value of a varnish used solely for indoor purposes is doubtful but, for outdoor decoration, such as is met with on the pagodas and shrines in Burma, it would be a considerable drawback. The use of this varnish by the cabinet-maker would, on account of its black colour, be necessarily restricted to a special class of work, and the varnish must be thinned with a larger percentage of turpentine than when it is used by the lacquer-worker.

To test the suitability of *thitsi* for varnishing furniture, a sample of varnish composed of *thitsi*, 1 part and *Boswellia serrata* oil, $\frac{1}{8}$th part was used for varnishing a *toon* wood table in the same way as if an ordinary varnish were used.

Three coats were applied which took a total of 6 days to dry; the result was most satisfactory and the resulting appearance compares most favourably with furniture varnished with similar imported varnishes or enamels.

For varnishing floors *thitsi* thinned with turpentine, and with ferric oxide as a drying agent, is reported to be of considerable use.

For enamelling leather, experiments have been carried out with a certain amount of success, and should be continued in this direction.

Besides the samples Nos. 1, 5 and 13, it would appear that samples Nos. 12, 14, 15 and 17 might be of some use owing to their quick drying properties, but it is a noteworthy fact that the use of ferric oxide considerably dulls the surface of the varnished articles. It is therefore considered that the use of ferric oxide should be restricted to the initial stages of the lacquer work, as described in the body of this note, since in these stages a glossy surface is not essential provided an even surface is obtained.

It seems even that the use of ferric oxide as a drying agent, in the initial stages of the lacquer work, would do away with the necessity of the underground drying cellar now employed in Burma, and would also accelerate the now very lengthy process. For the final stages of lacquer work, it will be necessary to use a varnish having a greater gloss than those samples containing ferric oxide, and for this purpose it is suggested that *thitsi* adulterated with gum arabic, provided a suitable thinning oil could be found, would be superior to pure *thitsi*. It is also suggested that for the finish shellac would be still better.

The action of turpentine or *Boswellia serrata* oil (an oil obtained by distillation of the resin of this tree) as a thinning medium in no way increases the drying capacity of the varnish, but allows the same to be spread in a thinner film; the use of these mediums is not altogether without disadvantages as they cause the *thitsi* to assume a reddish

brown colour in the sun. This disadvantage is, to a certain extent, counteracted by the use of ferric oxide, as none of the specimens of varnished woods, which were varnished with *thitsi* containing ferric oxide, were, to any very noticeable degree, affected in this way, although the test was a severe one.

The conclusions, therefore, which have been arrived at in the course of these investigations are :—

(*i*) The results given by Mr. Puran Singh are confirmed.

(*ii*) The use of *Boswellia serrata* oil or oil of turpentine in no way improves the drying capacity of the crude varnish : the addition of these oils only makes the substance thinner and more workable.

(*iii*) The addition of ferric oxide greatly increases the drying capacity of the varnish, apparently removes its poisonous properties, and retards the change in colour of the varnished articles when placed for any length of time in the sun. It must, however, be remembered that the addition of this drying agent tends to dull the gloss of the varnished articles.

(*iv*) The drying action of ferric oxide is probably due to oxidization, but it has been suggested that the action of the urushic acid of the varnish on the iron salt causes the latter to split up into a ferro-urushate salt.

(*v*) That, owing to the dulling action of the ferric oxide, it should be used only in small quantities when a high class finish is desired.

(*vi*) That the use of ferric oxide, as a drying agent in the initial stages of the lacquer process, would simplify the drying process and accelerate the production of the finished article.

(*vii*) That, owing to the restricted use to which a thick black varnish can be put, it seems unlikely that it will ever find its way on to the market in any considerable quantities except as a lacquer varnish, but there seems no reason why it should not compete favourably with the lacquer varnish now exported from China and largely used in Europe.

No experiments were undertaken to show the effect of strong alkalies or of acid on *thitsi* adulterated with ferric oxide.

9. Yield per Tree and Cost of Extraction.

The size and appearance of a tree is often misleading as to the amount of oleo-resin it will produce, as a large tree may produce very little

and a small or stunted tree may yield considerable quantities. A good tree is stated to yield $1\frac{1}{2}$ to 4 viss per annum. (1 viss=3·6 lbs.)

The Divisional Forest Officer, Shwegyin (1906), estimated the yield of a tree 5 feet in girth to be 15 to 20 lbs.

Mr. Blanford in writing to the Forest Economist, Dehra Dun, says: "A good big tree of the black variety on which many notches can be made should yield about 1 viss of oil per year. Smaller trees, if tapped economically, will only have 2 or 3 notches and will not yield as much.

"A good workman should be able to get 100 viss (360 lbs.) a year, and to get this he will have to superintend 500 notches. This is equivalent of about 200 trees. After the notch has been made a little time, the inner edge of the V must be shaved off, as otherwise the pores get choked up and the oil ceases to flow."

"The following is a rough estimate of the number of trees over 6 feet girth in the Division (Katha) :—

	Trees.
Indaw Range	5,000
Moda	1,000
Tigyaing Sub-division	5,000
Nankan Range	2,500
TOTAL	13,500

"There will probably be about the same number of trees between 4′ 6″ and 6′ breast-girth. If no trees are tapped below 4′ 6″, and all trees above are estimated to give an average of half a viss per annum, the total yield would be 13,500 viss per annum (48,600 lbs.) or 22 tons approximately.

"This should not be under the mark, as I have it on the authority of Maung Po Thin, Extra-Assistant Conservator of Forests in charge of Indaw Range, that the annual yield from the Indaw Range alone was formerly about 7,000 viss or about 11 tons.

"Only a rough estimate can be given of the cost of extraction. If it is assumed that a man can obtain 100 viss during the eight months that tapping can be done, and if it be assumed that he is paid Rs. 15 per mensem, the cost of obtaining 100 viss would be Rs. 120. The cost of extraction to the railway per 100 viss would not exceed Rs. 5 from even the most remote localities.

"The monopoly for collection of *thitsi* in each range is usually sold yearly by tender. Lately, however, the tenders have been very low and, in a great number of cases, no tender has been received at all.

" The following list shows the amounts paid for monopolies and the estimated outturn of the 10 years 1901-02 to 1910-11 :—

Katha Division.

Years.	Price of monopolies.	Estimated outturn as per annual reports.
	Rs.	(viss.)
1901-02	274	4,354
1902-03	140	2,700
1903-04	195	1,950
1904-05	248	2,598
1905-06	435	1,014
1906-07	358	3,577
1907-08	530	5,300
1908-09	600	6,000
1909-10	*Nil.*	*Nil.*
1910-11	*Nil.*	*Nil.*
TOTAL	2,780	27,493
AVERAGE	278	2,749

(1 viss=3·6 lbs.)

" The outturn is probably very much below the actual mark. Lately the demand for *thitsi* has fallen off considerably and this year (1911-12) only one monopoly was sold for Rs. 100 while, during the two years previous, there was no offer for *thitsi* at all."

" The amount which one man can collect, *viz.*, 100 viss (360 lbs.) per annum is generally agreed upon by other forest officers and may be taken as approximately correct, although it would be advisable to carry out experiments to verify this figure.

" In the absence of further figures, I have taken this as the basis of my calculations for estimating the price at which the varnish could be exported to Rangoon and to England.

	Rs.	A.	P.	
Price of extracting 100 viss (360 lbs.)	120	0	0	
Cost of kerosine oil tins, etc.	7	8	0	
Extraction to Katha riverside or railway	5	0	0	
Freight to Rangoon by steamer	2	14	0	
Contingencies	1	10	0	
TOTAL COST OF EXTRACTING 100 VISS	137	0	0	At Rangoon.
Taking 622 viss=1 ton, total cost of 1 ton	852	0	0	
Royalty on 1 ton, at Re. 1 per 10 viss	62	0	0	
TOTAL	914 =£61	0	0	At Rangoon.

	Rs.	A.	P.	
The freight to Europe before the War would be about .	30	0	0	per ton.
Shipping charges, dock dues, etc.	23	0	0	,, ,,
TOTAL .	53	0	0	
Total cost of landing 1 ton of *thitsi* varnish in England	967	0	0	
(At 1*s*. 4*d*. exchange) Approximately	£64	10*s*.	0	

10. Outturn from various parts of Burma and Prices.

The table given below shows the approximate quantities of the oleo-resin extracted from the Reserved and Unclassed forests of Burma in the 9 years 1907-08 to 1915-16. It is not always possible to obtain exact figures.

uantities of thitsi *in viss (3·6 lbs.) extracted during the last 9 years from the Forests of Burma.*

r.	PEGU CIRCLE.			TENASSERIM CIRCLE.			NORTHERN CIRCLE.			SOUTHERN CIRCLE.			BURMA GRAND TOTAL.
	From Reserved Forests.	From Unclassed Forests.	TOTAL.	From Reserved Forests.	From Unclassed Forests.	TOTAL.	From Reserved Forests.	From Unclassed Forests.	TOTAL.	From Reserved Forests.	From Unclassed Forests.	TOTAL.	
)8	..	300	300	..	..	..	1,000	43,900	44,900	3,600	30,800	34,400	79,600
)9	..	1,100	1,100	5,800	51,500	57,300	1,000	45,900	46,900	4,500	35,800	40,300	1,45,600
10	..	700	700	4,400	20,800	25,200	100	35,600	35,700	3,900	29,300	33,200	94,800
11	..	..	..	2,100	58,900	61,000	..	28,700	28,700	8,200	18,800	27,000	1,16,700
12	..	..	..	5,100	25,800	30,900	800	29,500	30,300	18,300	16,100	34,400	95,600
13	..	500	500	3,900	27,900	31,800	..	34,700	34,700	6,700	40,200	46,900	1,13,900
14	..	500	500	2,900	24,000	26,900	100	22,200	22,300	6,900	90,200	97,100	1,46,800
15	..	100	100	4,800	5,500	11,300	..	74,900	74,900	12,000	69,400	81,400	1,67,700
16	..	300	300	3,900	7,100	11,000	..	63,300	63,300	5,100	63,400	68,500	1,43,100

As will be seen, the average outturn from the Government forests for the last 9 years amounts to about 200 tons per annum, but the actual amount obtainable from all sources is probably considerably larger.

Notes from the various divisions in which a trade in Thitsi *exists, are given below.*

I. *Thayetmyo.—Thitsi* has not yet been extracted on a large scale in these forests up to date. Licenses have been issued from time to time, but only small quantities have been obtained. The Divisional Forest Officer reports, however, that large areas of forest containing *thitsi* occur on the west of the river which have not yet been worked, and it is probable that a good trade might be worked up from them.

II. *Prome.*—The tree is found in a number of forests in this division, and *thitsi* has been extracted under license, Rs. 450 having been received during the last 10 years in fees for the right to work certain forests. The Divisional Forest Officer estimates that about 4,500 viss have been extracted, but considers that the trade could be increased if good prices were obtained. He supplies the following list of dealers :—

Name.	Address.	Quantity of *thitsi* which can be supplied annually by each dealer, (in viss).	Price per 100 viss.
			Rs.
Mg. Shwe Shaung	Inmange, Paungde Township.	60	90
Mg. San Lon	Minbon		
	Do.		
Mg. Aung Ka	Sangyi, Shwedaung.		
Mg. Shwe Khet, Mg. Paw Se, Mg. Tun Aung	Phaungdin, Thegon Township.	75	93—12
Mg. San Min	Thabyedaung . Paukkaung Township.		

III. *Zigôn, Tharrawaddy* and *Henzada.*—The forests which contain *thitsi* in these divisions are scattered and small in area, and very little has been extracted.

IV. *North Toungoo.*—The right to tap the trees in each Range is sold for a lump sum to the highest tenderer. From 1905-06 to 1914-15 Rs. 11,302 was realised for the right to tap the trees, the estimated

outturn during the same period being about 2,67,000 viss. The *thitsi* is collected at Payogon, Thagaya, Yedashe and Nga-pe-in, and the following traders deal in it, the sale price noted being per 100 viss :—

Variety of *thitsi.*	Maung Me' Gwethe Range can supply annually	Maung Twé' Thagaya Range can supply annually	Maung Twa Yedashe Range can supply annually
Black	No demand .	500 viss at Rs. 100.	100 viss at Rs. 100.
Red	4,000 viss at Rs. 50 to 60.	100 viss at Rs. 50.	200 viss at Rs. 50.

The Divisional Forest Officer does not think that the trade can be increased.

V. *South Toungoo.*—Licenses are issued and, during the 10 years ending in June 1915, Rs. 2,222 was realised, the amount of *thitsi* extracted being estimated at 39,600 viss. Probably not more than 400 viss could be supplied annually from this division, at about Rs. 1-4 per viss. There are no regular dealers on a large scale.

VI. *Shwegyin.*—Licenses are issued annually for stated quantities of *thitsi*, generally up to about 50 viss. During the year ending June 1915, 1,210 viss of *thitsi* were extracted and Rs. 121 was paid in revenue. The Divisional Forest Officer supplies the names of local dealers given below, each of whom could probably supply about 100 viss annually at Rs. 150 per 100 viss. He considers that the trade could be stimulated if undertaken by men with capital.

Name.	Village.	Circle.	Sub-division or township.
Mg. Pan Sone . . . . Mg. Maung . . . . Mg. Kyein . . . . Mg. Kaing	Kalawmyaung	Mobaw . .	Shwegyin sub-division.
Mg. Kyan	Salugyaung .	Do. .	Do.
Mg. Lu . . . . . Mg. Pe Sa	Mewaing .	Do. .	Do.
Mg. Nge . . . . . Mg. Pan Nyo	Payagyi .	Thayebindat .	Kyaukkyi township.
Mg. San Paw . . . . . Mg. Pu Gaung . . .	Kyaungbya .	Kyaungbya .	Do.
Mg. Kyin Ya	Naung-U .	Mon . .	Do.

VII. *West Salween.*—The *thitsi* forests are distant from Moulmein, but a fairly large trade has been established. The monopoly of the right to collect the *thitsi* has been sold by auction each year, and during the 10 years 1905-06 to 1914-15 the amount received has averaged Rs. 900. The trade centres in Moulmein where enquiries should be made.

VIII. *Thaungyin.*—The sole right to collect *thitsi* is sold by auction, the sum realized during the 10 years 1905-06 to 1914-15 being Rs. 5,240, and the estimated annual outturn 1,500 viss. It is collected at Naungshwe, Naunglon, Lunmya, and Hlaingbwe and brought thence to Moulmein. It is not probable that the trade can be largely increased as the trees are very scattered.

IX. *Ataran.*—The following table shows the estimated outturn and revenue received during the 10 years up to 1914 :—

	Estimated outturn.	Revenue.
	Viss.	Rs.
By licenses from 1904-06 . .	200	20
By tender for monopoly from 1906-12	13,000	1,300
By licenses from 1912-14 . .	850	85
TOTAL .	14,050	1,405

The *thitsi* is collected at Tanyinkadeik, Ebaing and Winpok, and is thence brought to Moulmein. Trees are scattered and it is not probable that the trade can be much increased.

X. *Myitkyina and Bhamo.*—*Thitsi* is very scarce in both these divisions and cannot be considered of any commercial importance.

XI. *Katha.*—During the 10 years 1905-06 to 1914-15, a total sum of Rs. 2,323 has been realized by the sale of the sole right to collect *thitsi* in the various Ranges, the estimated outturn being 19,521 viss. Of recent years, the demand has greatly fallen off and very little has been extracted, but the Divisional Forest Officer considers that if prices again rise to about Rs. 150 per 100 viss—the minimum price delivered on the railway at which the collection will pay—a large quantity can be obtained.

XII. *Mu.*—In this division a very large trade in *thitsi* has existed for many years. The method of disposal of the right to collect it has varied, but at present annual licenses are issued to the men who tap the trees at Rs. 7-8 per man. The total amount of revenue realized during the 10 years 1905-06 to 1914-15 was Rs. 24,165 and about 15,000 viss of *thitsi* was extracted annually during that period. The Divisional

Forest Officer gives the following details regarding traders and quantity of *thitsi* available :—

Range.	Name.	Village.	Quantity that can be supplied per annum.
Yeu	Mg. Kyi Zo .	Thanwindaw .	About 10,000 viss.
	Mg. Shwe Pan .		
	Mg. Pyu . .		
Kyunhla	Mg. San E .	Inhla . .	About 250 viss.
	Mg. Po Kan .	Yeyein . .	,, 100 viss.

Prices vary very much. Black *thitsi* is most expensive and fetches up to Rs. 200 per 100 viss in Mandalay.

Near Kanbalu the tappers sometimes get Rs. 90 per 100 viss for the red *thitsi* and Rs. 100 for the black.

If the demand becomes good, there are sufficient trees in the reserved and unreserved forests to provide a very large quantity of *thitsi* annually.

XIII. *Upper Chindwin.*—The *thitsi* is extracted by licensees, and Rs. 698 has been realized from them during the last 10 years. The Divisional Forest Officer does not think that the trade can be much stimulated.

XIV. *Myittha.*—Under present arrangements licenses in Form VIII are issued, approximately one-third of the division being opened to extraction in any given year. Duty is collected on the *thitsi* extracted at Rs. 10 per 100 viss. During the 10 years 1905-06 to 1914-15, 25,442 viss of *thitsi* were extracted and Rs. 2,546 was realized as revenue. Maukkadaw is the centre of the trade and enquiries regarding it should be made there. Mg. Tun U, Mg. Tun Win, and Mg. Yo are the principal dealers there, and others are Mg. San Lin and Mg. Po Thit at Konyin, and Mg. Kyauk Lon at Moktha. Each of these men could probably supply 250 viss annually, the present rate being Rs. 14 per ten viss, while before the war it was Rs. 20. The Divisional Forest Officer thinks that when trade improves, the quantity available could be largely increased.

XV. *Lower Chindwin.*—Licenses are issued and royalty collected at Rs. 10 per 100 viss, the figures for the 10 years 1905-06 to 1914-15 being 29,342 viss extracted, realizing Rs. 5,362. The *thitsi* is collected

principally at Nyaungbinle, west of the Chindwin river, and Songon and Ngonchaung on the east bank. Practically all the *thitsi* is used locally, at Maungdaung and Kyaukka, in the manufacture of lacquered trays and cups, about 3,000 viss being required annually, and some of this comes from the Myittha and Mu divisions. The *thitsi* is sold locally, in kerosine oil tins containing 11 viss, at Rs. 15.

XVI. *Ruby Mines.*—There are large areas of forests containing *thitsi* in this division, but owing to difficulties with labour and with the licensees, none has been extracted since 1911-12. Before that, tenders were invited for the right to tap the trees in certain blocks of forest, and a license issued to the successful tenderer. The Divisional Forest Officer thinks that there is no reason why the forests should not yield about 10,000 viss of *thitsi* annually. Between 1895-96 and 1911-12, the revenue realized was Rs. 10,676, the quantity extracted being estimated at 160,000 viss ; but during 1907-08 and 1909-10, no *thitsi* was extracted. It could be easily collected on the banks of the Shweli and Irrawaddy rivers and could be brought down by boat thence to Mandalay.

XVII. *Mandalay and Northern Shan States.—Thitsi* is now obtained chiefly in the valley of the Madaya river above Mandalay and from the forests near Maymyo, but a large quantity was formerly obtained from the Northern Shan States. During the last ten years the following amounts have been extracted :—

Forest.	Viss.	Revenue realized.
		Rs.
Hsipaw and Hsum Hsai (Northern Shan States) . .	33,000	3,334
Maymyo	4,770	477
Madaya	29,875	3,405
TOTAL .	67,645	7,216

Since 1909 very little *thitsi* has been extracted from the Northern Shan States, but the Divisional Forest Officer considers that the trade might be revived by the reservation of forests so as to protect them from destruction by the villagers, who make large areas of temporary cultivation on these hills.

Prepaid licenses are issued to the tappers, but the number has decreased considerably of recent years. This may be due to the state

of the Mandalay market, and it is probable that the trade could again be brought to a high level by business-like methods.

The Divisional Forest Officer has supplied a list of 28 small traders, each of whom can supply some 20-40 viss per annum. Up-to-date information on this point can be obtained from him at any time. It is estimated that together these dealers can supply the following :—

Red *thitsi* (*Yeni thitsi*) .	770 viss per annum at Rs. 6 to 8 per 10 viss
Brown *thitsi* (*Yegyaung thitsi*)	900 viss per annum at Rs. 7 to 9 per 10 viss.
Black *thitsi* (*Yenet thitsi*) .	1,240 viss per annum at Rs. 11 to 12 per 10 viss.

XVIII. *Meiktila.*—The trade is at present of very small dimensions, but it could be increased if the demand for *thitsi* improves by allowing tapping in the Yeyaman and Pyetkaywe Reserves. Between August 1909 and March 1915, about 25,000 viss were extracted, the revenue realized being Rs. 2,468. The Divisional Forest Officer estimates that about 600 viss of each of the three varieties (black, brown, and red) can be obtained annually from the villagers in the north-eastern corner of the division at Rs. 150, 100 and 80 per 100 viss respectively.

XIX. *Pyinmana.*—The monopoly of the right to tap *thitsi* over certain defined areas is auctioned annually, and the revenue received from this source during the last ten years amounts to Rs. 12,395. A very rough estimate of the amount of *thitsi* extracted is 125,000 viss, and this is usually sold at the towns on the railway, where enquirers will find the dealers. The Divisional Forest Officer does not think that the trade can be much increased.

XX. *Southern Shan States.*—In the unclassed forests tapping is carried on without restriction or license of any kind, and the Divisional Forest Officer notes that the result of this wasteful procedure is that a large percentage of trees is killed annually and reproduction is seriously affected. No licenses to tap trees in the Reserves are or have been issued. No duty is leviable in the Southern Shan States, but on *thitsi* exported to Burma, Rs. 10 per 100 viss is paid at the first revenue station it reaches in Burma, or the Revenue stations at Aungban, Kalaw and Myindaik on the Southern Shan States Railway. The places where the greater part of the *thitsi* is collected on its way to Burma are, Aungban, Thazi, Myittha, Pyawbwe, Kyaukmé and Hsipaw. At these places the collectors themselves sell the *thitsi* to brokers. In the Bampon sub-division, the following are said to deal in *thitsi* on a fairly large scale :—

Mg. Po Chon of Kengtung.
Ai Lu and Mg. Khan of Tunhong.
Pwe Sa Gone of Mongpan.

Pu Sein of Nasan.

Kyaungtaga Chein of Ywathit.

The Hein of Namong.

The Hein and Kyaungtaga Pon of Naungtaung.

It is estimated that about 2,50,000 viss of *thitsi* were exported during the years 1912-15 to Burma. East of Taunggyi the price is about Rs. 85 per 100 viss. In the Myelat and in the Lawksawk State, the price varies from Rs. 65 to Rs. 75 for red *thitsi*, and from Rs. 90 to Rs. 100 for black *thitsi*.

XXI. In the *Yaw* division Rs. 957 only has been received during the last ten years as revenue on *thitsi*; the trees are few and scattered and the trade is of little importance.

XXII. *Minbu.*—The trade in these forests has never been of any great extent, but villagers have tapped the trees regularly for their own uses. Licenses are issued and the product is usually collected at Palangyin, Leinzu, Magyizu and Singaung in the Minbu district and Kyagan in the Magwe district, where a number of small traders live. Since 1906 10,000 viss have been extracted in the Minbu district, for which Government received Rs. 1,329 as revenue ; and during the same period 4,900 viss have been obtained in the Magwe district, Rs. 490 being realised. Inside Reserved forests, the license fee is Rs. 20 per hundred viss, and in unreserved forests, it is half as much.

General.

Thitsi, when it comes on the market, is graded into 3 classes according to its drying capacity : these classes are known sometimes by the terms (*i*) Pure black *thitsi*, (*ii*) Mixed black *thitsi* and (*iii*) Red *thitsi*.

Pure black *thitsi* is the best available on the market, and should be the pure unadulterated product ; the mixed black *thitsi* is said to be adulterated with the ash of rice husks, etc., and with a concoction made from the bark of *Albizzia stipulata* in order to improve the colour ; red *thitsi* is said to be still further adulterated, and to have derived its red colour from rain-water coming in contact with it at the time of collection. The three grades of material were analysed by Professor Dunstan at the Imperial Institute, London in 1914 with the following results :—

	Grade I per cent.	Grade II per cent.	Grade III per cent.
Water . . .	5.3	33·5	64·0
Ash	0·2	0·1	0·1
Matter insoluble in Benzene .	2·6	1·8	1·6

The residues obtained on drying the III grade were similar in appearance and general properties, so that it appears certain that grades II and III merely consist of grade I with the addition of water.

The following is a list of merchants who deal in *thitsi* in Rangoon :—

Daw Lay	36, Edward Street.
Po Kyaw	48, Edward Street.
Saw Lain Lee	19, Latter Street.
U Ba Oh	Panbinyat Quarter, Kemmendine.

The price of *thitsi* in 1916 was about Rs. 170, Rs. 130 and Rs. 100 for the 3 grades per 360 lbs.

Enquiries with regard to the working of the *thitsi* forests, dealers, and prices should be addressed to the Forest Research Officer, Maymyo Burma, or to Divisional Forest Officers, and samples of the oleo-resin can be obtained on application to the Forest Economist, Dehra Dun, United Provinces, India, or to the above-named.

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CALCUTTA
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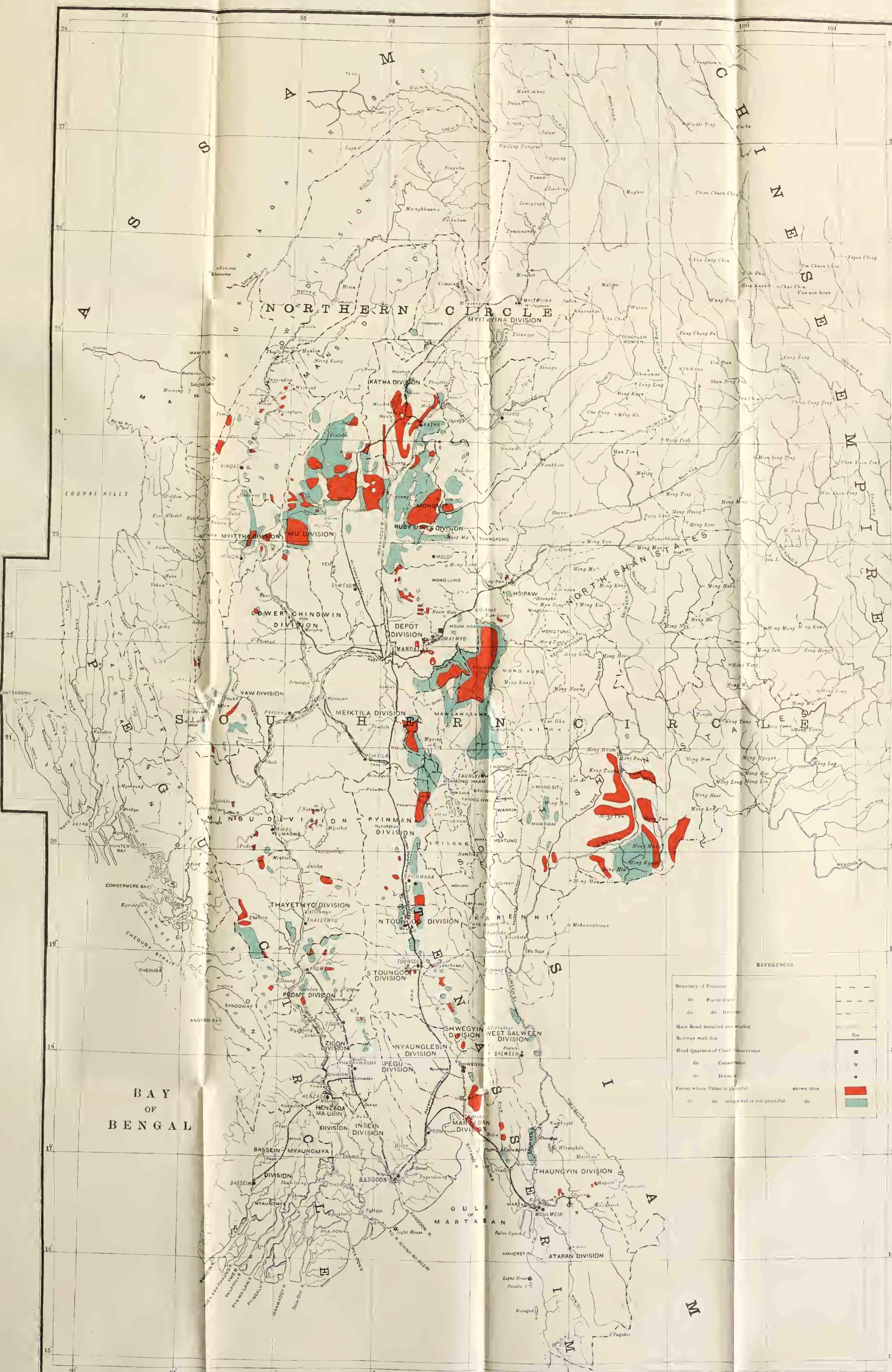
MAP OF BURMA

ILLUSTRATING THE NOTE ON THITSI

(MELANORRHOEA USITATA)

by Messrs Beeskin & Rodger

Scale 1=32 Miles



Reg. No. 8 F/17 700
Prepared in the Forest Map Office Dehra Dun, from information supplied by B B. Osmaston Esq.
President Forest Research Institute & College, Dehra Dun

Published under the direction of Colonel Sir S. G. Burrard, K.C.S.I., R.E., F.R.S., *Surveyor General of India.*
1917.

HELIOZINCOGRAPHED AT THE SURVEY OF INDIA OFFICES DEHRA DUN

INTRODUCTION.

THE following Record deals with the Antiseptic Experiments carried out in continuation of those, the results of which are given in Volume III, Part II of the *Indian Forest Records*. Chapter IV of that publication outlines the proposals for future investigation, which having been given effect to are described in the following note. When this enquiry was taken up, little or nothing was known in India about the antiseptic treatment of timbers, nor was any plant available in which to treat timber. It was therefore thought advisable to carry out the preliminary experiments by the cheapest and simplest methods possible, and the Open Tank process was adopted. Eight years and more have elapsed since this enquiry was started, and further experience has definitely fixed the value and limitations of the Open Tank process. It has been found suitable for treating posts, poles and sleepers of certain of the softer species of timber, but only in relatively small quantities; thus the outside limit for sleeper treatment by the Open Tank process is put at 50,000 B. G. sleepers per annum.

Though this note deals primarily with experiments carried out by the Open Tank process, in Part V are given the records of a limited number of experiments carried out in pressure plants.

The original scheme according to which the field experiments were to be carried out was drawn up in 1910, and was brought into effect at once, so that the sleepers treated at that time and laid down in 1911 have been six years in the line, while the laboratory experiments were started in January 1909, and have therefore been in progress sufficiently long to give definite results.

Part I reviews the work done up to the time the last note was prepared on the subject; Part II deals with the laboratory experiments; Part III describes the field experiments carried out by treating timber in Open Tanks, according to the prepared scheme; Part IV deals with the field experiments conducted according to the Open Tank process, outside the scope of the scheme; Part V is a record of experiments carried out with the Indian timbers in pressure cylinders; Part VI discusses the factors governing the treatment of timber when carried out under Indian conditions, with special reference to sleeper woods; and Part VII briefly outlines the processes by which timber, other than sleepers, might with advantage be treated in India.

Where reports or other documents have been quoted in the body of the report, the names of the authors, where possible, have been given.

The writer's best thanks are due to Messrs. Billson, Milward, Channer, Lyall and Bailey for help rendered in obtaining sleepers with which to carry out tests and in carrying out experiments in the United Provinces ; to Messrs. Leete, Marsden, Davis and Hefferman, all Burma Foresters, for assistance rendered in connection with supplying and treating sleepers at Pyinmana ; to Mr. Copleston for treating *Terminalia tomentosa* sleepers in the Bombay Presidency ; to Messrs. Thompson and A. L. Chattarjee for help rendered while treating sleepers in the Betul Division of the Central Provinces ; and to Messrs. Perrée, Jacob and Cooper for all the assistance they rendered in connection with the Assam experiments. Also to the Hon'ble Mr. A. B. Hawkins, Manager of the Assam Oil Co., for allowing him to carry out experiments in the Company's Pressure cylinder, which had been especially adapted for the purpose and for much help rendered and kindness shown, without which it would not have been possible to carry out the experiments with Assam species of timber.

On two occasions, Messrs. Rodger and Cox respectively acted for the writer while he was on leave, during which periods the experiments were in their charge, while to Mr. R. S. Troup, a former Forest Economist, is due the credit of the idea of restarting this enquiry, though he was transferred in 1909 before he was able to formulate a complete scheme of investigation.

During the course of the enquiry much valuable assistance has been obtained from Messrs. Howard, F.Weiss and Clyde H. Teesdale, Research Officers of the United States, Forest Service, who most kindly assisted the writer by supplying him with records of the results of their experiments and experience ; while acknowledgments are due to several Railway Engineers, who have, on many occasions, rendered assistance in order to facilitate the inspection of experimental sleepers in the line.

INDIAN FOREST RECORDS.

Vol. VI | 1918 | Part IV.

A Further Note on the Antiseptic Treatment of Timber, recording results obtained from past experiments.

By

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PART I.

PREVIOUS RECORDS AND OBJECTS OF THE INVESTIGATION.

1. Record of Previous Work.

A preliminary note dealing with the question of the Antiseptic Treatment of Timber in India was published in 1912, *Indian Forest Records*, Volume III, Part II. This note briefly outlined the past history of the Antiseptic Treatment of Timber in India, suggested Indian timbers suitable for treatment, discussed the various methods of treating timber in vogue at that time, gave the results of laboratory experiments carried out by the Open Tank process, and finally, laid down a scheme according to which it was proposed to carry out further experiments in the field.

The proposals made on pages 105 to 107 of the above-mentioned publication, have been given effect to and as six years have elapsed since the results of the various experiments have been published, it is thought advisable to place them on record without further delay.

2. Primary factors governing the treatment of timber in India.

In practically all parts of the world, the question of treating timber antiseptically has received consideration. In some countries it has already reached the position of a well-established industry, in others the work is in its infancy ; while, in recent years, a great impetus has been

given to the work, due to the increasing necessity for husbanding the world's timber supplies. Wherever the question of treating timber has arisen, certain main principles have had to be followed, though each locality has had to adapt these broad principles to local climatic conditions and to the indigenous species of timber to be treated.

In India, attempts were made as long ago as 1854 to treat indigenous timbers, while further attempts were made to do so in 1878, which led to no definite results. The chief causes of failure are attributed to the reluctance, on the part of the operators, to modify the accepted European principles of treatment to suit Indian conditions.

In most parts of India the climatic variations are extreme, periods of low and extremely high temperature occur, in winter many areas are excessively dry, while during the monsoon moisture is generally in excess. Such conditions rarely exist to the same degree in more temperate zones as, for instance, in Europe and North America, where either treated or untreated timber is never subjected to so trying conditions as it is in India. We have, therefore, factors in India which necessitate certain modifications in the established principles according to which timber should be treated. For instance, the direct effect of the drastic climatic conditions necessitate the greatest care in seasoning our timber, more so indeed than is necessary in countries enjoying a more equable climate. Again, owing to the occurrence of high temperatures, the coal-tar creosotes employed must contain exceptionally high boiling point fractions to obviate excessive evaporation, while the employment of salts is debarred, unless special protective measures are taken to obviate the leaching action due to excessive moisture. Too much importance cannot be attached to these three factors, when considering the possibility of treating timber in India.

3. Object of the investigation.

The primary objects of this investigation were two in number :—firstly, to endeavour to find uses for certain timbers, the demand for which was either less than the supply or non-existent and secondly, to ascertain whether, after treatment with an antiseptic, certain timbers, which come under the class of 'auxiliary species', could be rendered suitable for railway sleepers, and thus minimize the shortage of supplies caused by the ever-increasing demands made by the Indian Railway Companies.

There is another consideration which, though not of direct pecuniary interest, is of vital importance to the Forester. It has been stated elsewhere that in connection with sleepers, the timber-producing species

found in the Indian forests may be divided into " major " and " auxiliary " species. A classification based on similar lines can be evolved in connection with many other industries, such as cabinet work, cooperage, turnery, carriage work, etc., and though, by grouping all such timbers together and calling them " major species ", we obtain a fairly long list of timbers classified under this head, nevertheless the remaining auxiliary species form an infinitely larger group. For sylvicultural, as well as for economic reasons, it is obvious that the removal of mature trees of the auxiliary species should keep pace with the removal of those of greater value, and the only profitable way of doing this is to create a demand for the timbers, one of which, it is fairly certain, will be in the form of treated sleepers.

Persons not acquainted with the conditions of Indian Forestry might, with reason, wish to know why the auxiliary species should be chosen for experiment in connection with the treatment of sleepers, as in Europe and America nearly all species of timber are treated before being laid down as sleepers in the line. The answer is that the forests of India contain at least five species, namely Teak (*Tectona grandis*), Sâl (*Shorea robusta*), Pyinkado (*Xylia dolabriformis*), Deodar (*Cedrus Deodara*) and Nahor (*Mesua ferrea*) which, owing to their durability, require no treatment while, with the exception of Oak, this is not the case elsewhere. These five species of timber, as far as sleeper woods are concerned, are the " major species ", and though Teak is now only used in special cases, such as for bridges, etc., the other four species go to make up the greater percentage of wooden ties supplied by this country. The demand, however, is far in excess of the supply and this necessitates the treatment of the " auxiliary species " to make up the deficit.

The second point referred to concerns the shortage of wooden sleepers in India. Were all other factors to be ruled out of consideration, this factor alone would justify an investigation into the possibility of increasing the supply of sleepers by the treatment of hard-woods of insufficient durability. That difficulty has been experienced by the Railway Authorities in obtaining adequate supplies of sleepers is common knowledge and, as a proof of this assertion, if any is necessary, one has only to refer to the statements showing the imports, during recent years, of Australian and American sleepers into India and to remember that iron ties are commonly found in use on the main lines running far from the sleeper-producing localities.

Another factor has to be taken into consideration in connection with the demand for sleepers, and that is that the Railway Systems of India

are ever expanding and that the rate of construction is likely to increase very considerably after the war, so that not only will large numbers of sleepers be required for new lines, but the annual recurring demand for maintenance will also be increased. Such conditions further demonstrate the great importance of searching for new supplies of sleeper woods in India, the solution to which problem lies, without doubt, in the more extensive utilization of treated sleepers.

Taking the above facts into consideration, it was obviously incumbent on the Forest Department to endeavour not only to find new outlets for its timber but, as the largest timber-supplying agency in the country, to endeavour to put forward practical proposals by which the necessary supplies of sleepers could be obtained by the State and other Railway Companies. The most obvious step was for the Forest Department to turn its attention to those species found in the State Forests, the timber of which was mechanically suitable and which, after careful treatment, could be rendered sufficiently durable to meet the requirements of the Railway Engineers. The next step necessary to ensure success in such an investigation was to determine the available outturn and cost of extraction of suitable timbers, and then to proceed with the necessary experiments. The following chapters deal with the results of the investigations, experiments and conclusions deduced from the enquiry.

PART II.

THE RESULTS OF LABORATORY EXPERIMENTS.

1. Object of the Laboratory Experiments.

Laboratory experiments, of which a full description is given in the previous publication on this subject, were instituted in order (*i*) to obtain a rough idea as to the most suitable antiseptics or groups of antiseptic oils or salts with which to conduct tests in the field. (*ii*) to determine the relative absorption by soft, moderately soft and hard woods when treated in Open Tanks, and the corresponding period of immersion required for each species, (*iii*) to obtain data as to the durability of the treated specimens, and lastly (*iv*) to obtain a rough estimate of the probable cost of treatment. Results obtained from such experiments can only be considered as a stepping-stone to more exhaustive trials and,

though of value, especially to the investigator, should, owing to their limitations, be accepted with caution.

2. Description of the Laboratory Experiments.

The experiments have been carried out on a fairly extensive scale, in so far as the number of antiseptic solutions tested is concerned, no less than 23 different salts and oils, or combination of both having been given a trial. The species of timber selected for trial were twelve in number, comprising all grades from extremely hard to some of the softest timbers of India. The tests carried out being of a strictly comparative nature, so as to keep all factors constant, the same species of timber were employed throughout, the specimens were cut to a uniform size of $18'' \times 2'' \times 2''$, and the period of immersion, when possible, was kept constant. It is an established fact that hard-woods absorb less solution than soft-woods during a stated period of immersion so that, to effectually protect a hard species, it is generally necessary to allow a longer period of immersion than would be necessary for a soft-wood species. Again, the amount of absorption permissible is directly proportionate to the cost of the solution employed. These conditions were waived in order to obtain uniform results and to form a correct comparative estimate of the value of the various antiseptics employed. While carrying out the field experiments on a more extensive scale, as described in Part III, full consideration was given to the amount of antiseptic absorbed and to the corresponding cost of treatment of each individual species of timber.

A further precaution taken was to experiment not only with thoroughly seasoned timber, but also to prepare the necessary specimens of each species from the same log. In this way, possible variations in the structure and density of the two specimens of any individual species were avoided, and a true comparison of their relative merits, in a treated and untreated state, rendered possible.

After treatment in the laboratory, a full description of which is given in the former note on the subject, the treated and untreated specimens were put into the ground together, in a place known to be infested by white-ants, and each group inspected periodically. The only exception to the above procedure was in the case of the Powellized specimens, of which no less than 147 treated and untreated pieces were laid down and kept under observation. The only other point requiring mention is that, owing to the number of antiseptic solutions dealt with, all the tests could not be started at one and the same time, while each group had to

be dealt with as the seasoned timber and the antiseptic solutions became available.

3. Results of the Laboratory Experiments.

In the last publication on this subject, it was only possible to give records of durability covering a period of a little over a year. The first group of experiments in connection with the Powellizing process were commenced in April 1909, the next with *Avenarius Carbolineum* oil, *Atlas* solution and *Coal Tar* in June 1909, after which specimens treated with the other antiseptics were laid down up till the end of 1914 : the majority, however, were laid down between 1909 and 1911.

In describing these experiments, the classification adopted has been to place the oils in two groups, according to the time the experiments have been in progress. The salts are dealt with separately in two groups, while the salts and oils combined are dealt with in one group.

It has not been found possible to tabulate the results carried out with the Powellized specimens, together with the other laboratory experiments, as they were started at an earlier date by Mr. Troup, formerly Forest Economist, and were carried out on different lines. They are therefore recorded separately.

The durability results are shown in diagrams, while a précis of results is given in tabulated form.

(i) First group of Laboratory Experiments.

Results of Experiments with Powellized specimens.

Diagram I.*

This diagram has been prepared with the object of demonstrating the durability of the treated, as compared with the untreated specimens of each species. The specimens have been under observation from six to seven years, so that sufficient time has elapsed to permit all untreated and some of the treated woods to decay.

To illustrate the results obtained as a whole, the following table has been prepared, which gives the number of treated and untreated specimens originally laid down : those at present in a damaged condition, though still serviceable, and those removed after having been destroyed by white-ants or fungus attack :—

* This will be found in the pocket at the end of this publication.

TABLE I.

Treated.						Untreated.					
Number laid down.	Sound.	Slightly damaged.	Damaged, though serviceable.	Destroyed and removed.	Missing.	Number laid down.	Sound.	Slightly damaged	Damaged, though serviceable.	Destroyed and removed.	Missing.
77	6	17	12	34	8	66	0	2	17	40	7

The outstanding feature of the above results is that, after being 6 to 7 years in the ground, not a single untreated specimen is now absolutely sound, while only 19 are still serviceable, thus clearly indicating the drastic conditions under which the timber was tested.

The treated specimens compare very favourably with those which were not treated; omitting those which were lost while the experiment was in progress, 50 per cent. of those treated as against 32 per cent. of the untreated specimens remain and are still serviceable. Another way of illustrating the results obtained, is to calculate the average life of the treated and untreated specimens, basing the calculation on the time they have been in the ground up to the last date of inspection. By so doing, we find that the average life of the treated pieces up to date is five years and two months and of the untreated pieces, three years and seven months. As time goes on, this difference will increase in favour of the treated timber, as already over 66 per cent. of the untreated, as against under 50 per cent. of the treated specimens, have been removed.

From the above results, it might be argued that Powellizing does not really protect the timber from decay or white-ants, as nearly half the treated specimens have had to be removed within seven years. This would be a correct assumption, were it not for the fact that many of the timbers tested are of an extremely perishable nature such as, for instance, Nos. 3, 6, 10, 26, 44, 45, 46, 47, 51, 65, 69 and 74, which probably nothing but a very heavy absorption of coal-tar creosote would render sufficiently durable to enable them to last seven years.

Another point requiring comment is that of the first 24 treated specimens shown in the diagram, laid down in April 1909, only 7 have failed ; of the next 31 specimens, laid down in November 1909, 11 have failed ; while of the remaining 22 which were laid down in April 1910, 15 have failed. Such results are not easily explained. Had the first and second batches contained no soft woods, the results would explain themselves, but this was not the case. The only explanation that can be offered is that the method of treatment was not so thorough in the case of the latter batch of specimens, as it was when dealing with the two former, the impregnation having, in every instance, been carried out for the Forest Department by the Powell Process Company.

As a whole the results, so far as the Powell process is concerned, may be regarded as satisfactory, taking into consideration the drastic conditions under which the experiment was carried out.

(*ii*) SECOND GROUP OF LABORATORY EXPERIMENTS.

Experiments carried out with Avenarius Carbolineum *oil,* Coal Tar, Jodelite, Solignum, *Pinus excelsa* Tar *and* Green oil.

This group of experiments have been in progress from six to seven years.

In the case of the *Avenarius Carbolineum, Coal Tar, Solignum* and Pinus excelsa *Tar* specimens, the treatment consisted in painting on the solution hot, a liberal coating being given. In the case of the *Jodelite* and *Green oil* specimens, the treatment was by immersion in hot solutions for 10 to 15 minutes. Details of this work are given in the previous publication.

DIAGRAM II.*

In the accompanying diagram, the results of the experiments are shown so as to illustrate the relative value of the different antiseptics when applied to the different species. To compare the values of the different antiseptics, the following table has been prepared, which gives the number of specimens of each series still remaining sound or sufficiently serviceable not to necessitate their removal, and the average life up to date of the twelve treated and twelve untreated specimens of each group :—

* This will be found in the pocket at the end of this publication.

Photo.-Mechl. Dept., Thomason College, Roorkee. Photo by T. B. Chitrakar.

Showing state of specimens after 6 to 7 years. — Left-hand pair, treated specimen is on left side, and the reverse is the case in central and right-hand pairs. — Left hand *Pinus longifolia* treated with Jodelite, central *Pterocarpus macrocarpus*

TABLE II.

	Treated.						Untreated.			
Antiseptic oil with which the different species of timber were treated.	Number of years under observation.		Number originally laid down.	Number remaining.	Average durability, in years.		Number originally laid down.	Number remaining.	Average durability, in years.	
	Yrs.	mos.			Yrs.	mos.			Yrs.	mos.
1. Avenarius Carbolineum.	6	10	12	9*	5	2	12	2*		10
2. Coal Tar . .	6	10	12	2	3	9	12	2	2	10
3. Jodelite . .	6	9	12	7	5	4	12	3	2	8
4. Solignum . .	6	7	12	7	5	7	12	3	3	3
5. *Pinus excelsa* Tar .	6	5	12	3	3	11	12	4	2	11
6. Green oil . .	6	0	12	9	5	8	12	4	2	10

NOTE.—* Out of 9 specimens shown as remaining, five are now missing, while one of the two untreated specimens is also missing, having been lost, probably stolen, after having been under observation for five years and five months.

By referring to diagram II, it will be seen that the most striking results have been obtained by treating soft-wood species; for instance, the *Boswellia serrata* stake treated with *Solignum* has lasted six years and nine months, and is now in a damaged condition but still serviceable, while the excessive damage caused by white-ants and fungus attack rendered the removal of the untreated stake necessary after being in the ground four months. Or again, the *Bombax* stake treated with *Green oil* lasted six years, while the untreated pieces only lasted three months. Similar examples can be given with reference to most of the soft-wood timbers treated with creosote oils.

These experiments were carried out primarily with the object of determining the relative value of these oils, the actual life of any individual treated piece being of secondary importance. It is therefore necessary to examine Table II in detail. Six antiseptics are dealt with, amongst these *Coal Tar*, which was added as a basis for comparison, as its use is universal all over the world and its value recognized. The average life up to date of the specimens treated with *Coal Tar* is three years and nine months, while that of the stakes treated with Tar of *Pinus excelsa* is three years and eleven months, and therefore these two Tars are of about equal value. *Jodelite, Solignum, Avenarius Carbolineum* and *Green oil,* which are *Coal Tar creosote* preparations, all show far better results than *Coal Tar.* Of these *Green oil* stands first, the treated specimens having lasted five years and eight months, out of a possible six years. *Solignum* comes next, the specimens having lasted five years

and seven months, out of a possible six years and seven months; while *Jodelite* has given slightly better results than *Avenarius Carbolineum* oil. There is little to choose between these *Coal-tar creosote* products, all of which have given satisfactory results, when taking into consideration the extremely perishable nature of the timbers used, *viz.*, *Boswellia serrata*, the conifers, *Bombax malabaricum* and *Odina Wodier*.

The relative value of these antiseptics can also be based on the number of stakes in each group still remaining in the ground. It will be seen that the evidence is strongly in favour of the creosote products, as only two stakes treated with *Coal Tar* and three treated with *Pinus excelsa Tar* remain sound, as against nine of each treated with *Avenarius Carbolineum* and *Green oil* and seven of each treated with *Jodelite* and *Solignum*.

Turning again to Table II, it will be seen that the average life of the untreated stakes of each group only varies between two years and eight months and three years and three months—a fact clearly demonstrating the uniformity of the conditions under which the experiments were carried out.

(*iii*) Third group of Laboratory Experiments.

Experiments carried out with Crésoyle, Anthrol, Burma oil, *and* Liquid Fuel *from Borneo.*

These experiments naturally fall into two categories, *i.e.*, those dealing with *Crésoyle* and *Anthrol*, both coal-tar products, which have been in progress five years or more; and those with *Burma oil* and *Liquid Fuel*, both belonging to the petroleum series, the experiments with which have been three and a half years in progress.

The treatment of these groups of specimens varied somewhat, those treated with *Crésoyle* having been immersed for 10 minutes in a cold solution; while those treated with *Anthrol* were immersed in a hot bath for an hour and allowed to remain in the solution as it cooled down, for 16 hours; while the *Burma oil* and *Liquid Fuel* specimens were treated in hot oil for 15 minutes and 45 minutes respectively.

Diagram III.*

Diagram III records the durability of each individual treated and untreated specimen.

Here again, there is a striking contrast between the treated and untreated soft-woods, which is even more marked in the case of the *Creosote oils* than in that of the *Petroleum oils*.

A critical analysis of the relative value of these oils is given in the following Table :—

* This will be found in the pocket at the end of this publication.

TABLE III.

Antiseptics with which the different species of timber were treated.	Treated. Number of years under observation.	Number originally laid down.	Number remaining.	Average durability, in years.	Untreated. Number originally laid down.	Number remaining.	Average durability, in years.
	Yrs. mos.			Yrs. mos.			Yrs. mos.
Crésoyle . . .	5 6	12	9	5 2	12	3	2
Anthrol . . .	5 0	12	12	5 0	12	3	2
Burma oil . .	3 6	12	10	3 4	12	5	2
Liquid Fuel . .	3 6	12	10	3 4	12	3	1

The results obtained so far with *Crésoyle* and *Anthrol* are quite satisfactory: of the specimens treated with the latter, none have failed up to date. The reason for this is due to the method of treatment, as also to the value of the oil. Of the experiments described so far, the treatment has consisted in either soaking the specimens for one hour in hot oil or in immersing the specimens for 10 or 15 minutes in a bath of cold oil. In the case of the specimens treated with *Anthrol*, the treatment was far more drastic, as they were immersed in hot oil for an hour and allowed to remain in the solution for a further period of 16 hours, while it cooled down, resulting in a complete penetration in the case of the soft-wood species and a fairly heavy absorption by the harder timbers. This experiment demonstrates the possibility of preserving even the softest timbers, such as *Boswellia serrata, Bombax malabaricum* and *Odina Wodier* for five years and more with a creosote oil.

Turning to the oils with a petroleum base, it will be seen that they, too, protect timber, for though their toxic value is low, their waterproofing properties are considerable, while they render the timber distasteful to white-ants. The experiments with *Burma oil* and *Liquid Fuel* have not as yet been long enough in progress to enable one to form a definite idea as to their value, though it is thought that the results obtained will be less satisfactory than those obtained with *Coal-tar creosotes.* The results with *Burma oil and Liquid Fuel* based on either their average durability or the number of specimens remaining after three and a half years, are exactly equal.

(*iv*) FOURTH GROUP OF LABORATORY EXPERIMENTS.

Experiments carried out with Atlas solution, Béllit, Sodium Fluoride *and* Chloride of Zinc *and* Hylinit.

The experiments dealt with up to this point have all been carried out with oils derived from *Coal-tar* or from a Petroleum base. This

group of experiments deals with salt solutions, such as *Atlas*, a patent solution, which is poisonous; *Béllit*, another patent salt, made up of 80 per cent. *Sodium Fluoride*, 12·5 per cent. *Dinitro-phenol* and 6·5 per cent. *Aniline*; the third salt is composed of 3·5 per cent. Chloride of Zinc, 3·5 per cent. *Sodium Fluoride* and the rest water, while *Hylinit* is a patent solution, the composition of which is unknown though it is stated to be non-poisonous.

The method by which the timber was treated with *Atlas* was to immerse the specimens in a 20 per cent. cold solution for 24 hours. Concentrated *Béllit* was mixed in 44 parts of water and the specimens immersed for 48 hours, the solution having been heated to 120°F. in the initial stages. In the case of *Chloride of Zinc* and *Sodium Fluoride*, a 7 per cent. solution was made up and the timber left to soak for 12 days, while a 10 per cent. solution of *Hylinit* was employed and a 24 hours immersion period given to the specimens.

Diagram IV.*

Diagram IV illustrates the durability of the treated and untreated specimens in each group of experiments.

A glance at this diagram shows that the general durability of the treated specimens is below that of those treated with oil.

To determine the relative value of these salts, Table IV has been prepared :—

TABLE IV.

	Treated.				Untreated.		
Antiseptics with which the different species of timber were treated.	Number of years under observation.	Number originally laid down.	Number remaining.	Average durability, in years.	Number originally laid down.	Number remaining.	Average durability, in years.
	Yrs. mos.			Yrs. mos.			Yrs. mos.
Atlas solution . .	5 10	12	4*	4 6	12	2†	2 10
Béllit . . .	5 7	12	3	3 4	12	3	2 6
Sodium Fluoride and Chloride of Zinc.	5 7	12	6	4 5	12	2	2 7
Hylinit . . .	5 5	12	4	3 9	12	4	2 11

* This will be found in the pocket at the end of this publication.

† Note.—These specimens are now missing, so the experiment has had to be closed.

The most noticeable point in the above table is the relatively few treated specimens remaining after 5 to 6 years, which is attributed not so much to the want of toxic properties in the salts, as to the fact that the salts have been washed and leached out of the timber by excessive moisture. Taking, as an example, the *Atlas* experiment, four out of twelve specimens remain after 5 years and 10 months, of which the timber of two of them is so durable that it is doubtful whether it requires treatment. *Béllit* has given equally poor results, while *Hylinit* is little better than either *Béllit* or *Atlas*.

Of these salts, *Sodium Fluoride* and *Chloride of Zinc* have given the best results which, however, compare unfavourably with the results obtained with the oil solutions. The superiority of *Coal tar creosotes* over salt solutions, in damp climates, is further emphasized by the fact that the timber was treated by applying the oil with a brush or by a short immersion period, as against a long period of immersion often covering several days, in the case of the salt solutions.

(*e*) FIFTH GROUP OF LABORATORY EXPERIMENTS.

Experiments carried out with Anticide, McDaugall's insecticide, Mort-ant *and* Burnettizine.

This group of experiments is virtually a continuation of group IV, it having been separated from that series only in order to facilitate description, and on account of the experiments having been started at a later date than those described above. All four antiseptics dealt with are patents.

The method of treating the timber, in the case of *Anticide*, was to allow it to remain in the cold solution for 64 hours. The specimens treated with *Mort-ant* were given a 15 minutes immersion, those treated with *McDougall's insecticide* a 24 hours immersion in a 4 per cent. solution, while the solution of *Burnettizine* was made up to 40 per cent. strength, heated to 170°F. and the specimens allowed to remain submerged for 64 hours.

The reason for subjecting the timber to different periods of immersion was due to the recommendations of the patentees of the various substances, and to the period of immersion having to be regulated in direct proportion to the cost of the solution. Generally speaking, salt solutions are cheap as compared with coal-tar products, hence the long periods of immersion permissible in the case of experiment coming under groups IV and V.

DIAGRAM V.*

The results obtained with *Anticide, McDougall's insecticide, Mort-ant* and *Burnettizine* are given in Diagram V. They cover a period of from 2 years to 4½ years; the results, therefore, cannot be said to be final.

It will be seen that certain specimens were not laid down in the *Anticide* experiment, which is to be regretted, as it breaks the sequence of these experiments as a whole which, it must be remembered, were instituted primarily to determine the relative value of certain antiseptic solutions, the durability of any individual timber being of secondary importance.

The records given in Diagram V are tabulated below :—

TABLE V.

	TREATED.				UNTREATED.		
Antiseptics with which the different species of timber were treated.	Number of years under observation.	Number originally laid down.	Number remaining.	Average durability, in years.	Number originally laid down.	Number remaining.	Average durability, in years,
	Yrs. mos.			Yrs. mos.			Yrs. mos.
Anticide . . .	4 6	6	5	4 1	6	0	1 3
McDougall's insecticide	3 8	11	9	3 7	9	2	1 7
Mort-ant . . .	3 9	11	5	2 10	11	5	2 3
Burnettizine . .	2 0	12	8	1 7	12	8	1 8

The results, as will be seen both from the Diagram and Table, are quite satisfactory in the case of *Anticide,* as though one out of six of the specimens has failed, the average life of the six untreated specimens was only one year and three months, while five of the treated specimens have already lasted four and a half years. Nine out of eleven specimens treated with *McDougall's insecticide* remain after three years and eight months, as against two untreated specimens. Taking into consideration that, of the nine treated species remaining, five are for all intents and purposes sound, the results are fairly satisfactory. *Mort-ant* has given less favourable results than either of the two previous solutions; five remain sound out of eleven treated specimens after three years and nine months, while the durability of the treated and untreated specimens is practically the same. The *Burnettizine* experiment has only been in progress two years, so no definite conclusion can be drawn; the fact

* This will be found in the pocket at the end of this publication.

that out of twelve treated specimens four have had to be removed, and that four others are already seriously damaged, does not hold out any great hopes that this solution will prove to be suitable when employed under Indian conditions.

(*vi*) Sixth group of Laboratory Experiments.

Experiments carried out with Crésol-Calcium, Aczol *and* Barol.

These antiseptics are combinations of salts and oils, so mixed together as to form emulsions. They are the results of an attempt to overcome certain difficulties in connection with treatment of timber with salts alone. To overcome these difficulties, and at the same time to reduce the cost of treatment, such substances as *Crésol-Calcium, Aczol* and *Barol* have appeared on the market. These preparations aim at combining a salt with an oil and treating the timber with both at the same time ; later on, under "Field Experiments," the results of treating timber first with a salt and when dry with an oil will be discussed.

The timber treated with *Crésol-Calcium,* was immersed in a 10 per cent. solution for 7 days. The concentrated solution when mixed with water resembled an emulsion of lime, and gave off powerful phénolic and crésolic fumes. *Aczol* is also a patent solution, probably made up of phénolic substances and copper. To prepare the solution, 2 oz. of *Aczol* were mixed with 20 oz. of *Ammonia Hydrate* and 50 lbs. of water and the specimens allowed to remain in this solution for 24 hours. *Barol* is advertised as a preservative containing oil of great wood-preserving qualities and copper compounds. The timber in this case was immersed in a solution heated to 90°C., for one hour and allowed to remain in the liquid for a further period of 23 hours, while it cooled down.

Diagram VI.*

Diagram VI illustrates the durability of the specimens treated with *Crésol-Calcium, Aczol* and *Barol.*

When studying this diagram, it must be borne in mind that the *Crésol-Calcium* experiment has been in progress five years and five months, and that the *Aczol* and *Barol* experiments have only been in progress between two and two and a half years, hence the want of uniformity of the lines of durability.

The following table summarizes the position of affairs in respect to this group of experiments :—

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* This will be found in the pocket at the end of this publication.

TABLE VI.

Treated.					Untreated.		
Antiseptics with which the different species of timber were treated.	Number of years under observation.	Number originally laid down.	Number remaining.	Average durability, in years.	Number originally laid down.	Number remaining.	Average durability, in years.
	Yrs. mos.			Yrs. mos.			Yrs. mos.
Crésol-Calcium . .	5 5	12	4	2 9	12	4	2 11
Aczol . . .	2 5	10	6	2 0	10	5	1 9
Barol . . .	2 3	12*	12	2 3	12	6	1 11

* Of these one has been lost after 2 years and three months.

The results obtained with *Crésol-Calcium* are extremely poor : only four out of twelve treated specimens remain: in fact, the treated specimens have given no better results than the untreated ones. The results of the field experiments with sleepers treated with *Crésol-Calcium* will be dealt with in the next chapter. The results of *Aczol* are equally disappointing ; for, though there are still six treated specimens remaining out of ten, this is a poor result considering that the experiment has only been in progress two years and five months. *Barol* so far shows considerable promise, as eleven specimens are not only present but absolutely sound (the twelfth is missing, but as the species in question is Sâl—the most durable of them all—the record may be taken as complete.) It is yet too early to form any definite conclusions as to the value of *Barol,* though it is safe to say that it promises well.

4. Conclusions deduced from the Laboratory Experiments.

As the experiments with various species of *Powellized* timber were started before and were not carried out on the same basis as the other experiments, it is necessary to discuss the results separately. The results obtained are very fairly satisfactory, especially with respect to the first two batches of specimens. The hard and moderately hard woods treated, as compared with the untreated specimens, have fared in proportion better than the treated soft-woods. The reason for this is probably due to the fact that the saccharine and arsenic solution is less liable to be washed out of the hard-wood timber, than is the case with soft-woods. The results of the field experiments with *Powellized* sleepers will be discussed hereafter.

The outstanding feature of the experiments with various *Coal-tar creosote* products, as opposed to salt solutions, is the evidence obtained in favour of the former. It is possible to deduce very striking figures in evidence of this statement by inspecting the

various diagrams. Leaving out of consideration the experiments with crude *Coal-Tar*, *Tar* from *Pinus excelsa*, *Burma oil* and *Liquid Fuel*, diagrams II and III deal with *Coal-tar creosotes*, while diagram IV demonstrates the durability of timbers treated with *salt* solutions. All these experiments have been in progress for five years or more, but we may take the results at exactly five years, so as to bring all results down to a common denominator. The results are as follows :—

TABLE VII.

	Name of antiseptic.	Greatest possible life of all the specimens of each group, added together.	Actual total life of all specimens. Treated.	Actual total life of all specimens. Untreated.	Number of specimens remaining, out of 12 laid down. Treated.	Number of specimens remaining, out of 12 laid down. Untreated
		Years.	Yrs. mos.	Yrs. mos.		
Coal-tar creosote products.	Avenarius Carbolineum.	60	54 9	31 4	8	3
	Jodelite		51 4	26 8	8	3
	Solignum		54 2	32 2	9	4
	Green oil		58 9	31 7	9	4
	Crésoyle		56 9	25 2	11	3
	Anthrol		60 0	24 6	12	3
	TOTAL AVERAGE	60	55 11	28 7	Average 9·5	Average 3·3
	Average per specimen.	5	4 8	2 4·5		
Salts.	Atlas	60	49 2	31 9	5	3
	Bèllit		37 0	28 4	4	4
	Sodium Fluoride and Chloride of Zinc.		49 0	28 11	8	4
	Hylinit		42 9	32 6	5	4
	TOTAL AVERAGE	60	44 6	30 4	Average 5·5	Average 3·7
	Average per specimen	5	3 8·5	2 6·3		

The figures speak for themselves : the specimens treated with *Coal-tar creosote* products have lasted on an average four years and eight months and those treated with salts three years and eight and a half months, out of a possible five years. It may, therefore, be stated with safety that *creosote* products are preferable to *salt* solutions for treating timber for use in India. It is just possible that *salt* solutions might answer in the very dry localities, such as in Sind and parts of the Punjab, though that point still remains to be proved.

The value of each oil or salt or combination of salt and oil has been dealt with after recording the result of each individual experiment, so need not be repeated here ; suffice it to say, that the final selection of any given antiseptic which has given satisfactory results, must be decided on its cost and the amount of the substance necessary to preserve the timber for a stated period. These points will come under general discussion in Part VI.

PART III.

RESULTS OF FIELD EXPERIMENTS, TIMBER TREATED BY THE OPEN TANK PROCESS.

1. Object of the Experiments.

The laboratory experiments, the results of which have already been recorded, were carried out with the object of ascertaining the value of certain antiseptics, the durability of any given species after treatment being of secondary consideration. The Field Experiments, on the other hand, were carried out with the primary object of ascertaining the durability of certain timbers after treatment, when used as railway sleepers. Further, by dealing with a fairly large number of sleepers, it was possible to ascertain certain other factors, namely, (*i*) the approximate cost of felling, extraction and conversion of the various species, (*ii*) the approximate cost of treatment with different antiseptics, and (*iii*) to determine the period of immersion required in order to make the sleepers take up the required amount of antiseptic solution.

2. Scope of the Experiments.

(*i*) NUMBER OF SLEEPERS TREATED.

The original scheme, according to which the field experiments were to be carried out, contemplated the treatment of 20,000 sleepers made up of five different species, 1,000 of each to be treated every year, and

each year's treatment to be different. As the work progressed from year to year, the numbers of sleepers treated had to be modified and finally 7,980 sleepers in all were handed over to the State Railways.

(*ii*) SELECTION OF SPECIES.

The first point to be decided upon was the selection of the species of timber with which to carry out the experiments. Some difference of opinion was experienced as to which species should be selected, it being essential that (*i*) the species be available in large quantities, (*ii*) the cost of extraction should not be excessive, (*iii*) the timber be mechanically strong enough to withstand the wear and tear to which it would be subjected, and (*iv*) the timber should lend itself to treatment. It was finally decided to subject five species of timber to trial : namely, those of *Dipterocarpus tuberculatus*, *D. alatus*, *Pinus longifolia*, *P. excelsa* and *Terminalia tomentosa*, and it is with these five species that all the Open Tank experiments have been carried out.

3. Antiseptics used.

In connection with the choice of antiseptics it was necessary to consider, (*i*) which solution would probably render the timber most durable and (*ii*) the cost. When settling the first point, the results obtained from the laboratory experiments were naturally taken into consideration, as also the mass of literature available on the subject from Europe and America. In preference to salt solutions, everything pointed to the use of high boiling-point oils in a country like India, where the temperature during a portion of the year is very high and the moisture during the monsoon period is excessive. Were durability the only factor to be considered, it would not have been necessary to consider experimenting with other antiseptics. Cost, however, claims nearly equal attention, so that it was decided to experiment also with combined salt and oil solutions. Further, as at that time the *Powell* process was being much discussed, it also called for consideration. It was finally decided to experiment with (*i*) the *Powell* process, (*ii*) with *Avenarius Carbolineum* oil, (*iii*) with a mixed impregnation of *Chloride of zinc*, the salt being protected by a coating of *Green oil*, and (*iv*) with a mixture of *Solignum* and *Rangoon oil* or *Liquid Fuel.*

4. Method of Treatment.

The relative merits of the Open Tank treatment as opposed to Pressure plants will be discussed hereafter. In the case of these experiments everything pointed to the use of Open Tanks, for the reason that little

was known at the time about the treatment of Indian timbers; while the scale on which the experiments were to be carried out did not justify the erection of three expensive Pressure plants, one in the Punjab, another in the Central Provinces and a third in Burma. Since then the results of these experiments have proved the possibilities of treated sleepers in India, so that further experiments have been carried out in pressure plants.

5. Brief description of the Antiseptics employed.

(*i*) Powellizing.

Powellizing consists in immersing the timber in a *Saccharine* solution containing small quantities of *arsenic*, gradually heated up to a fairly high temperature, the time of immersion depending on the density and size of the timber to be treated. After removal the timber is placed in a drying chamber until it is thoroughly dry. It is virtually an *Open Tank* process, as no pressure is applied during treatment. No reliable information was available at the time the experiments were started as to the merits of this process, except somewhat meagre records from Australia and those obtained from laboratory experiments carried out at Dehra Dun. The cost of treatment is relatively high, though not prohibitive.

(*ii*) Avenarius Carbolineum.

Avenarius Carbolineum oil is a *Coal-tar creosote*, some of the constituents of which have high boiling points. It was produced in France and Germany, where its use has been demonstrated for treatment in *Open Tanks*. It has given satisfactory results in the laboratory experiments, while the results obtained with this oil by Professor Henry of the National Forest School at Nancy, are most encouraging. It could only be procured in India before the war at the high price of 2 rupees per gallon, which precludes more than 5 lbs. to 7 lbs. of the oil being introduced into a B. G. sleeper. It remains to be seen whether this very limited amount of oil is sufficient to preserve the timber from decay for a reasonable time: the laboratory results certainly indicate that this is the case.

(*iii*) Chloride of Zinc and Green oil.

Treating timber by a mixed impregnation method is a somewhat speculative experiment. Its chief aim is to reduce the cost of treatment. *Chloride of Zinc* alone is a well-known antiseptic in connection with the treatment of timber, the use of which has been discussed in the previous

note on this subject. It has been in use on the Continent and in parts of America for upwards of 50 years, but its drawback is that it leaches out of the timber and, if used in strong solutions, attacks the metals; its great merit is that it is cheap. *Green oil* is a commercial name for a good grade of *Coal-tar creosote,* with high boiling points and a relatively low percentage of tar acids. Its cost in England is $4\frac{1}{2}d.$ per gallon, naked, while it costs about 13 annas per gallon to land it anywhere in the centre of the Indian Peninsula. The treatment with two such solutions consists in first allowing the timber to absorb as much of the salt solution as possible, and then after the sleepers have dried thoroughly, in plunging them in the hot oil bath and permitting them to absorb a relatively small quantity of oil. This has the effect of forming a thin shell of oil-impregnated tissue on the outside, enclosing and preventing the salt from being washed out by moisture and at the same time preventing the foot-rail from coming into direct contact with the salt. The process is cheap when compared with a moderately heavy impregnation of creosote oil only; for, though the salt solution is allowed to penetrate to the centre of the timber it only costs 2 annas 6 pies to treat a B. G. sleeper, while the amount of oil the sleeper is allowed to absorb is only about 25 per cent. of the quantity necessary when treating with oil alone.

(*iv*) SOLIGNUM AND RANGOON OIL

The reason for selecting *Solignum* for trial was that records of its use in India for protecting timber, other than Railway sleepers, are decidedly encouraging, even when only small quantities of oil have been used. *Solignum* is, however, an expensive oil. With a view, therefore, of reducing the total cost and allowing more complete impregnation, it was decided to mix it with equal quantities of *Rangoon oil,* which is relatively cheap.

6. Powellizing Experiments carried out in the Field.

(*i*) ARRANGEMENTS MADE TO CARRY OUT THE EXPERIMENTS AND THE NUMBER OF SLEEPERS TREATED.

The arrangements made to carry out these experiments were that the Forest Department should supply the sleepers f.o.r., that the Railway Board should pay the cost of freight to and from the impregnating plant in Bombay and that the Powell Company should treat 1,000 sleepers free of cost, the cost of impregnating the remainder being borne by the Forest Department.

The number of treated sleepers actually handed over to the Railway Board was as follows :—

TABLE VIII.

Species.	Whence obtained.	Number of treated sleepers actually handed over to Railway Board.
Pinus longifolia	Chakrata Division, United Provinces.	704
„ *excelsa*	Ditto .	809
Dipterocarpus tuberculatus . . .	Pyinmana Division, Burma.	432
„ *alatus*	Ditto .	126
Terminalia tomentosa	West Division, Kanara, Bombay.	860
TOTAL .		2,931

It was originally contemplated that 5,000 sleepers should be treated but, owing to the Powell Company in India closing down, just as the remaining *Dipterocarp* sleepers were on the point of being despatched from Burma, and also in a lesser degree to rejections of faulty sleepers, the experiment had to be considerably curtailed.

(*ii*) COST OF TREATMENT.

It is not possible to form a correct idea of the cost of delivering Powellized sleepers to a Railway Company, based on the experience gained in carrying out these experiments. In the first place, the cost of railing sleepers from Northern India or railing them to Rangoon and then shipping them to Bombay, was excessive. Were it contemplated to supply *Powellized* sleepers to a Railway in India or Burma, the obvious way to do so would be to erect the treating plant in the vicinity of the forest from which the sleepers were to be extracted or near the Railway line. Again, owing to the first batch of *Dipterocarp* sleepers having been converted green and some of the pine sleepers having been prepared from faulty logs, the number of rejections was unduly high and unless the price realized by selling such rejections be deducted from the cost of preparing the total number of sleepers, the figure of cost is incorrect. Experience was, however, gained in carrying out this set of experiments, which resulted in better methods of working being adopted in carrying out the second group of experiments.

In consideration of the above facts, the following calculations are based on the actual number of treated sleepers handed over to the Railway Companies, had they been delivered on rail near the forests from which they were obtained; in other words, leaving out of account freight to and from Bombay.

Royalty charges on the timber are also excluded from these estimates.

Cost of felling, converting, extracting and Powellizing 1,513 *Pinus longifolia* and *P. excelsa* B. G. sleepers :—

	Rs.	A.	P.
Cost of felling and conversion	482	0	0
Cost of extraction to rail	997	0	0
Cost of treatment	1,560	0	0
Miscellaneous charges for handling, branding, etc.	41	0	0
TOTAL	3,080	0	0

Cost of felling, converting, extraction and Powellizing 555 *Dipterocarp* B. G. sleepers :—

	Rs.	A.	P.
Cost of felling	395	0	0
Cost of conversion	388	0	0
Cost of carting to rail	117	0	0
Cost of treatment	573	0	0
Contractors' profits	287	0	0
Miscellaneous charges for handling, branding, etc.	86	0	0
TOTAL	1,846	0	0

Cost of felling, converting, extracting and Powellizing 860 *Terminalia tomentosa* B. G. sleepers :—

	Rs.	A.	P.
Cost of conversion and felling	1,293	0	0
Cost of extraction	587	0	0
Cost of treatment	887	0	0
Miscellaneous charges for handling, branding, etc.	92	0	0
TOTAL	2,859	0	0

The above figures do not represent what was actually spent on these experiments, as they exclude the cost of preparing sleepers which had to be rejected and which were afterwards disposed of at a profit.

The point of primary interest is the cost of putting a treated sleeper on the market. Based on the above figures, the price comes to Rs. 2-0-7 per B. G. Pine sleeper, to Rs. 3-5-3 for B. G. *Dipterocarp* sleepers, and to Rs. 3-5-2 for B. G. *Terminalia tomentosa* sleepers.

No account is taken in the above calculation of either royalty on the timber or on the process. Were these charges included *Pinus excelsa* B. G. sleepers would cost approximately Rs. 5-8-0 and *Pinus longifolia* B. G. sleepers, Rs. 5-0-0 each ; while the two *Dipterocarps* would come to Rs. 4-8-0 per B. G. sleeper and *Terminalia tomentosa* to Rs. 4-11-0 per B. G. sleeper. The reason for the *Pinus excelsa* sleepers costing more than the other species is, that the royalty on the timber is high, the untreated timber finding a ready market in Northern India.

(*iii*) NOTES OF THE BEHAVIOUR OF THE POWELLIZED SLEEPERS, AFTER BEING LAID IN THE LINE.

The above sleepers, after treatment, were handed over to the Railway authorities, and the localities where the sleepers have been laid down, dates of doing so, together with the most recent inspection notes are shown in detail in the accompanying table.

Photo.-Mechl. Dept., Thomason College, Roorkee. Photo by T. B. Chitrakar.

TABLE IX.

Record of Powellized sleepers.

Species.	Number of sleepers laid down.	Locality where laid down.	Date of laying in the line.	Date of last inspection.	Inspection notes	REMARKS.
Pinus longifolia (Chir.)	152 B. G. sleepers.	Hardwar-Lhaksar Section, Oudh and Rohilkhund Railway. Mile 3/17 to 4/1.	15th January 1912.	22nd November 1917.	Thirty-five sleepers are slightly and twelve badly cracked but still serviceable. Two show signs of decay at ends. No sleepers have been removed since last inspection. The sleepers on the whole are in fair order. (Inspected by Executive Engineer and Forest Economist.)	Put in the Road on bearing plates and fixed with screw spikes. Branded P. I. C. 1—1912.
Ditto	152 B. G. .	Cawnpore-Lucknow branch, Oudh and Rohilkhand Railway. Mile 1/2½ to 1/4¾.	December 1911	November 1917.	Thirteen sleepers split and seventeen are slightly so, while two show signs of decay but serviceable, spikes loose where sleepers have split. They seem to have changed little since last year, and are in fair order. Bearing plates showing a tendency to sink into the timber. The remarks made last year regarding laying the sleepers heart up still apply with equal force. (Inspected by Executive Engineer, and Forest Economist.)	Branded P. L. C. on bearing plates. Three screw spikes per bearing plate.
Ditto	197 B. G. .	Sukkur-Karachi Section, North-Western Railway. Mile 261/14 to 261/77.	5th December 1911.	14th September 1916.	*With bearing plates.*—White-ant attack nil. Indentation of bearing plates into sleepers nil. Holding power of spikes good. General condition good. Those which are somewhat deteriorated are cracked and a few warped. *Without bearing plates.*—Same as above except that rails are cutting into sleepers slightly and dog-spikes on the outer side of rail are crushing the fibre behind them. (Inspected by Mr. H. N. Glass, Assistant Engineer.)	99 with and 98 without bearing plates. Branded P. L. and tin plates.

Record of Powellized sleepers—contd.

Species.	Number of sleepers laid down.	Locality where laid down.	Date of laying in the line.	Date of last inspection.	Inspection notes.	REMARKS.
Pinus longifolia (Chir.)	101 B. G.	Sibi-Quetta Section, North-Western Railway, near Hirok. Mile 206/16 to 206/17.	1st to 10th March 1912.	16th May 1916	(*i*) *Sleepers laid with bearing plates.*—Six sleepers are badly cracked, 18 others shewing signs of cracking which are getting worse. There is little cutting by the bearing plate. The spikes holding well. (*ii*) *Sleepers laid without bearing plates.*—Seven badly cracked, 13 others cracked which will probably develop. Quite 50 per cent. of the sleepers are being cut at rail-seats. Dog-spikes are holding. These are a poor lot of sleepers. (Inspected by the Executive Engineer, Quetta District, North-Western Railway.)	52 with and 49 without bearing plates marked thus 3*c*-12.
Ditto	210 B. G.	Ranaghat Station, Eastern Bengal State Railway. Mile 46/4 to 46/10.	April 1912	23rd June 1917	These sleepers and those of *Pinus excelsa* are laid in the line mixed; a few sleepers were taken out for inspection, and were found in some cases to be slightly decayed on the under-surface, not sufficiently so to justify rejection in any case. A few show signs of cracking, though taking them as a whole they are in a fair condition. Rail cut not more than before. White-ant attack not increased since last inspection at which time it was slight. (Inspected by Mr. Taylor, Sub-Divisional Officer and Forest Economist.)	Sleepers marked 'C' and re-marked with studded nails.
Pinus excelsa (Kail)	103 B. G.	Hardwar-Lhaksar Section, Oudh and Rohilkhand Railway. Mile 4/1 to 4/2.	7th February 1912.	22nd November 1917.	Two sleepers removed since the sleepers were laid down, none since last inspection. Of these sleepers, 11 are slightly and 5 badly cracked and two show slight signs of decay at ends; they are in good order and generally better than the Chir. (Inspected by Executive Engineer and Forest Economist.)	On bearing plates and fixed with screw spikes. Branded $\frac{\text{P. L.K.}}{\text{1—1912.}}$

Ditto	108 B. G. sleepers.	Cawnpore-Lucknow Branch, Oudh and Rohilkhand Railway. Mile 1/4¾ to 1/6.	December 1911	November 1917.	Fifteen sleepers are split and seventeen slightly so but all are serviceable, except one; the spikes where the sleepers are splitting are not holding very tight. In appearance they are much as they were last year, and show several years' more life. (Inspected by Executive Engineer and Forest Economist.)	Branded P. L. K. 12—11. Laid on bearing plates, and fixed with three screw spikes. Ends not bound.
Ditto	116 B. G.	Sukkur-Karachi Section, North-Western Railway. Mile 261/12 to 261/14.	5th December 1911.	14th September 1916.	*With bearing plates.*—General condition good. White-ant attack nil. Indentation of rail into sleeper marked, considerable in some. Spikes are crushing the fibre at the back. Those which are deteriorated are cracked. *Without bearing plates.*—General condition good. Those which are deteriorated are cracked at ends. (Inspected by Mr. H. N. Glass, Assistant Engineer.)	58 laid with, and 58 without, bearing plates. Branded P. E. and tin plates.
Ditto	99 B. G.	Sibi-Quetta Section, North-Western Railway, near Hirok. Mile 206/15 to 206/16.	1st to 10th March 1912.	16th May 1916.	(*i*) *Sleepers laid with bearing plates.*—These sleepers are very much superior to the Chir, *Pinus longifolia*, and on the whole their condition is quite good. None are badly cracked, 3 are cracked through at one end, 8 have minor cracks which are not serious. There is a slight tendency for the bearing plate to cut into the sleepers. Spikes are holding well. (*ii*) *Sleepers laid without bearing plates.*—90 per cent. are being cut into at the rail-cut. One sleeper is badly cracked, 2 are cracked but not getting worse, and six have developed minor cracks which so far are not serious. Spikes holding well. These sleepers are much superior to 'Chir,' *Pinus longifolia*. (Inspected by the Executive Engineer, Quetta District, North-Western Railway.)	49 laid with, and 50 without, bearing plates. Marked thus K. 3—12

Record of Powellized sleepers—contd.

Species.	Number of sleepers laid down.	Locality where laid down.	Date of laying in the line.	Date of last inspection.	Inspection notes.	REMARKS.
Pinus excelsa (Kail)	246 B. G.	Ranaghat Station, Eastern Bengal State Railway. Mile 46/4 to 46/10.	April 1912	23rd June 1917.	These sleepers and those of *Pinus longifolia* are laid in the line mixed; a few sleepers were taken out for inspection, and were found in some cases to be slightly decayed on the under-surface, not sufficiently so to justify rejection in any case. A few show signs of cracking, though taking them as a whole they are in a fair condition. Rail-cut not more than before. White-ant attack not increased since last inspection, at which time it was slight. (Inspected by Mr. Taylor, Sub-Divisional Officer and Forest Economist.)	Branded 'K' and to be re-studded with nails.
Dipterocarpus tuberculatus (In.)	434 B. G.	Down line 4,000 feet from the centre of Naihati platform. Mile 22/11 to 22/20. Eastern Bengal State Railway.	6th October 1911.	Ditto	None have been removed to date. Their condition is much the same as when they were laid in the line, the cracking is remarkably slight. They may be said to be doing very well. Screw spike hole not enlarged though rail cut is up to one-eighth inch. (Inspected by Mr. Taylor, Sub-Divisional Officer and Forest Economist.)	Marked serially 1 to 438 of which No. 320, 327, 346, and 427 were originally missing. Branded "DT."
Dipterocarpus alatus (Kanyin.)	121 B. G.	Ditto	Ditto	Ditto	None have been removed to date. See report on *Dipterocarpus tuberculatus* sleepers. These are exactly in the same condition though showing slightly more tendency to crack. (Inspected by Mr. Taylor, Sub-Divisional Officer and Forest Economist.)	Marked serially 439 to 560, of which No. 510 is missing. Branded "DA."
Terminalia tomentosa (Sain.)	131 B. G.	Hardwar-Lhaksar Section, Oudh and Rohilkhand Railway. Mile 3/16 to 3/17.	1st September 1911.	22nd November 1917.	Six sleepers removed since they were laid down in the line, none have been removed since last inspection. The rail-cut is insignificant and there are no signs of white-ant attack. Out of the 131 sleepers, 19 are slightly and 17 badly cracked, and 3 show slight signs of decay. On the whole they are in good condition. (Inspected by Executive Engineer and Forest Economist.)	Without bearing plates. Branded P. L. T. / 9—1911.

Ditto	187 B. G.	Cawnpore-Lucknow Branch, Oudh and Rohilkhand Railway. Mile 1/6 to 1/8½.	September 1911	24th November 1917.	Five badly split but not unserviceable, eight split, and the remainder present much the same appearance as they did last year. Spikes holding well. The sleepers were bound at the ends with wire, which in some cases has proved beneficial. Sleepers generally in good order. (Inspected by Executive Engineer and Forest Economist.)	Laid without bearing plates 2 dog spikes per rail seat. Ends bound with wire. Branded $\frac{\text{T. T.}}{11}$
Ditto	158 B. G.	Sukkur-Karachi Section, North-Western Railway. Mile 261/9 to 261/12.	21st July 1911	14th September 1916.	*Sleepers with bearing plates.*—General condition good. White-ant attack nil. Grip of spikes good. Indentation of bearing plates nil. The sleepers which are somewhat deteriorated are cracked at ends. *Sleepers without bearing plates.*—Same as above. Many of the outer dog-spikes have crushed the fibre at the back. Indentation of rail negligible. (Inspected by Mr. H. N. Glass, Assistant Engineer.)	79 laid with and 79 without bearing plates. Branded. T. T. and tin plates.
Ditto	116 B. G.	Sibi-Quetta Section, North-Western Railway, near Hirok. Mile 206/17 to 206/18.	1st to 15th August 1911.	16th May 1916	(*i*) *58 sleepers laid with bearing plates*—Condition generally fairly good. Three badly cracked, 5 cracked and tending to become worse, 15 with shakes, but tending to open out particularly at dog-spikes. No evidence of cutting by bearing plates. Spikes holding. (*ii*) *58 sleepers laid without bearing plates.*—Condition good. None badly cracked, 7 cracked and tending to get worse, and 4 containing shakes, with a special tendency to develop near the dog-spike. There is a slight tendency for the rail-seat to cut into the sleepers. The spikes are holding. This lot of sleepers is superior to No. (*i*). (Inspected by Executive Engineer, Quetta District, North-Western Railway.)	58 laid with and 58 without bearing plates. Marked thus $\boxed{\frac{\text{T. T.}}{8\text{—}11}}$
Ditto	122 B. G.	North of Ranaghat, on Down line, mile 46/10 to 46/11. Eastern Bengal State Railway.	1st June 1913	23rd June 1917	None removed to date. As good as the day they were laid in the line. (Inspected by Mr. Taylor, Sub-Divisional Officer and Forest Economist.)	
Ditto	101 B. G.	North of Ranaghat, on Down line, near Chelaram's brick-field. Siding mile 46/11 to 46/12.	22nd June 1913	Ditto	Ditto Ditto.	

(*iv*) NOTE ON THE ABOVE EXPERIMENTS.

Pinus longifolia, ' Chir.'—The sleepers have been in the line from 5 to 6 years and, out of 912 laid down, 5 have been removed during that period. The only report of white-ants attacking the sleepers comes from those laid in the Ranaghat section, Eastern Bengal State Railway, where one sleeper was found to be severely and six slightly damaged. No dry or wet rot has as yet set in so that, as far as the process is concerned, the results to date are very satisfactory, when taking into consideration that this timber barely lasts two years when laid in the line in an untreated state. The reports all mention splitting of the timber, which is in some cases serious. This tendency of the timber to split has probably nothing to do with the treatment, but is an inherent fault of this species of timber. On the other hand, the somewhat unsatisfactory condition of these sleepers has, without doubt, been accentuated by insufficient care having been exercised in selecting them before treatment, and especially by including many sleepers which contained the core of the tree. Again, from results obtained by carrying out these experiments, it has been proved that in the case of this species of timber the sleepers should be laid heart-wood up and sap-wood down, as it is the exposure of the sap-wood to hot sun that increases the tendency of the timber to split ; moreover, by laying the heart-wood up a much harder bearing surface is presented to the rail-seat. The tendency of the rail to cut into the timber is not serious, though bearing-plates are necessary. Taking into consideration the class of timber dealt with and the mistakes made in the selection and laying of the sleepers, the results to date may be considered extremely satisfactory.

Pinus excelsa, ' Kail.'—The sleepers have been in the line from 5 to 6 years and out of 677 laid down, two have been removed during that period. There are no reports of white-ants having attacked the sleepers. The tendency of the timber to crack is somewhat less marked than in the case of ' Chir,' though the cut at rail-seat is generally deeper than is the case in that species. The spikes are holding well though, owing to the relative softness of the timber, service plates and screws are absolutely necessary. From results to date, the ' Kail ' have shown slightly better results than ' Chir,' due to the greater tendency of the latter species to split. The results to date with *Powellized* ' Kail ' are distinctly good, as the life of the untreated timber when used as a sleeper is not longer than that of ' Chir.'

Dipterocarpus tuberculatus, ' In ' or ' Eng.'—The sleepers were laid down nearly 6 years ago and up to date none have been removed. Their condition has changed little since being laid in the line : only fine surface

Photo.-Mechl. Dept., Thomason College, Roorkee. Photo by T. B. Chitrakar.

Pinus longifolia Powellized sleepers, after five years in the line. Lucknow-Cawnpore-Branch, O. & R. Ry.

Note.—Left-hand sleeper cut from core of a twisted fibre tree, centre sleeper laid sap-wood up, right-hand sleeper laid heart-wood up, which demonstrates the value of laying Pine sleepers in this way.

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Photo.-Mechl. Dept., Thomason College, Roorkee. Photo by T. B. Chitrakar.

cracks have developed, the screw holes have not enlarged, though the cut under the rail-seat is, in some cases, up to $\frac{1}{8}''$ deep. These *Powellized* ' In ' sleepers may be said to be doing very well, when taking into consideration that the life of untreated ' In ' sleepers is hardly 5 years. The Sâl (*Shorea robusta*) sleepers laid in the adjoining line at the same time as above, do not present so good an appearance as the ' In ' sleepers.

Dipterocarpus alatus, ' Kanyin.'—No sleepers have been removed during the six years they have been in the line. Their condition is very similar to that of the ' In ' sleepers, with which they are laid in the same line. The tendency to split in these sleepers is somewhat more marked than in the case of ' In.' The spikes are holding well, while the cut under the rail-seat shows, as it does in the case of the ' In ' sleepers, the necessity of using bearing-plates. The results to date of *Powellized* ' Kanyin ' sleepers is decidedly satisfactory.

Terminalia tomentosa or ' Asain.'—The sleepers have been in the line nearly 6 years and, out of 814 laid down, 9 have been removed during that period. The removals have been due, in every case, to original faults. It is known that these sleepers were cut from old trees and tops left after logging, hence many of the sleepers show faults. As a matter of fact, this is probably the best of the five species tested for sleepers, as the timber is extremely hard and, though liable to develop cracks, its tendency to do so is not greater than that of ' Pyinkado ' (*Xylia dolabriformis*), which is classed as one of the best sleeper woods of India. The spikes hold very firmly, the tendency to cut under the rail-seat is insignificant and no bearing-plates are necessary. The results to date with this species are very satisfactory.

(*v*) OTHER EXPERIMENTS WITH POWELLIZED SLEEPERS IN BURMA, NOT INCLUDED IN THE ABOVE SCHEME.

A record of considerable value is available from Burma, with respect to 100 sleepers of ten different species of timber which, after having been *Powellized*, were laid down together with an equal number of untreated sleepers of the same species in April 1908, near Pyinmana, on the Rangoon-Mandalay section of the Burma Railways. Their condition is recorded below, the information having been taken from a joint report submitted by Mr. A. Rodger, Forest Research Officer, Burma, and the Assistant Engineer, Yamethin, Burma Railways, after their inspection of the 3rd June 1916.

TABLE X.

Record of Powellized sleepers from Burma.

Species.	Date on which the sleepers were laid down.	Number of sleepers laid down.	Condition of *Powellized* sleepers on the 3rd June 1916.	Condition of untreated sleepers on 3rd June 1916.
Dipterocarpus tuberculatus or 'In' wood.	About March 1908.	10 treated, 10 untreated.	The 6 left in 1915 are still in, all are rather bad, and 3 must be removed at once.	The two remaining sleepers seen in 1915 have been removed rotten and cracked.
Dipterocarpus alatus or 'Kanyin.'	Ditto	Ditto	The 5 remaining sleepers were removed in 1915, as all were cracked and rotten.	All removed by 1913.
Homalium tomentosum	Ditto	Ditto	The 3 remaining sleepers have been removed in 1916, all were cracked and rotten. Experiment closed.	All removed by 1911.
Schleichera trijuga .	Ditto	Ditto	All removed by end of 1914, rotten and spikes not holding.	All removed by 1913.
Terminalia belerica .	Ditto	Ditto	The 2 remaining bad sleepers left last year have been removed in 1916. Experiment closed.	All removed by 1909.
Terminalia tomentosa .	Ditto	Ditto	Six are left not rotten, cracked but serviceable for another year.	All removed by 1915.
Careya arborea . .	September 1907.	9 treated, 11 untreated.	Four still left, fairly good, will last 2 more years.	The remaining 4 were removed in 1915, badly cracked and rotten.
Pinus Khasya . .	Ditto	Ditto	*Three still left, 2 will last for four more months, one must be removed at once, all rotting and splitting.	Four removed in 1908, and 7 removed in 1909. Experiment closed.

* Date of last inspection 18th June 1916.

The sleepers referred to above have been in the line for eight years up to the date of last inspection. Sixty per cent. of the *Dipterocarpus tuberculatus* sleepers have lasted over eight years, three out of ten being left after that period, while the last of the untreated sleepers were removed after being seven years in the line. The *Dipterocarpus alatus* sleepers were all removed within eight years, 50 per cent. of them having lasted that period, while all the untreated sleepers of that species were removed within 5 years. The last of the *Homalium tomentosum Powellized* sleepers were removed after 8 years, the untreated sleepers having lasted 3 years. The *Schleichera trijuga* treated and untreated sleepers both fared badly, lasting 6 years and 5 years respectively. The difference

between the treated and untreated *Terminalia belerica* sleepers is very marked : the former lasted up to 8 years, the latter only one year. The *Terminalia tomentosa* sleepers have done best : six out of ten are still in the line after 8 years, being still serviceable, whereas all the untreated sleepers were rejected within seven years. The *Careya arborea* sleepers have done better than might have been expected : four treated sleepers are still in the line and are in fair condition, whereas all the untreated sleepers were rejected within seven years. The *Pinus Khasya* have done moderately well, three still remaining after 9 years.

In the case of all the above species, the treated compare favourably with the untreated sleepers. From former experiments carried out on an extensive scale with untreated sleepers of *Dipterocarpus tuberculatus* and *D. alatus*, it was ascertained that their life is about 4 years, while that of *Terminalia tomentosa* sleepers is from 5 to 7 years, so that it may be stated definitely that these three species are considerably benefited by *Powellizing*. This is an important point, as all three species are plentiful in Burma.

(*vi*) EXPERIMENTS WITH POWELLIZED SLEEPERS ON THE BOMBAY, BARODA AND CENTRAL INDIA RAILWAY.

An experimental lot of 5000 *Red Sarayah* (probably *Shorea leprosula*) Powellized sleepers were laid down in February 1911, on the Idar-Brahmakhed Extension of the Bombay, Baroda and Central India Railway. The Executive Engineer, Sabarmati, inspected these sleepers in June 1917 and reported as follows :—

" I made an inspection of these sleepers on 18th June 1917—

" *White-ants* :—There had been rain subsequent to the sleepers having been opened out. This tended to remove traces of white-ants. However, I broke open several sleepers that showed signs of attacks from white-ants and am forwarding you 2 typical pieces of these sleepers which, to my mind, prove clearly that, at least after a period of over six years, the process does not cause timber to be immune from attacks of white-ants. You will notice that the wood in process of being destroyed is quite sound and also that the ants have riddled well into the central part of the sleepers. When these sleepers were broken open the white-ants were in evidence in great numbers.

"*Renewals* :—Previous to April 1916 no sleepers were renewed. Since then 300 sleepers have been renewed out of the 4,100 Powellized sleepers put in from mile 55-5 to 57-11. This gives a renewal percentage of 7·3.

" From my inspection I consider that 10 per cent. should now be renewed. Of these sleepers the greater number have become unserviceable owing to cracks and a lesser number owing to the timber having

perished. The tendency of these sleepers to crack, especially when exposed to the sun, has already been noted in previous reports.

"*Fastenings* —I do not find that the fastenings are excessively corroded as compared with those in contact with untreated sleepers."

The record of another experiment with *Powellized* sleepers is available from the Bombay, Baroda and Central India Railway. In July 1911 this railway laid down in the Broach District, a locality notorious for white-ants, the following *Powellized* sleepers for trial :—

9 pieces of *Chloroxylon Swietenia*
5 ,, of *Terminalia tomentosa.*
4 ,, of *Odina Wodier.*
7 ,, of Powtik (Singapore Sarayah).

In August 1915, the Executive Engineer reported that "the sleepers "were all sound, except those marked T. T., which had developed fine "cracks. None of them, however, had been attacked by white-ants." Of the above timbers, the first two would last untreated more than four years, while *Odina Wodier* would certainly not last as long as that in an untreated state. As to the durability of untreated *Sarayah* timber, nothing is known further than that in an untreated state it is not durable when used as sleepers.

(*vii*) General conclusions based on the results of experiments with Powellized timber.

To form a correct estimate of the value of the *Powell* process from the results of the above described experiments it is of importance to differentiate between the rejections due to mechanical defects in the timber and rejections due to deterioration of the fibre or attack by white-ants. In the case of the laboratory experiments, in which the specimens were laid down in three batches, all those which failed of the first two batches were rejected owing to white-ant attack, while some of those of the third batch were rejected due to a combination of dry rot and white-ant attack, and the rest to white-ant attack only. The cause of this is ascribed to faulty treatment due to early inexperience. The reason why white-ants attacked the treated soft-wood specimens is attributed to the fact that the arsenic has, in course of time, been washed out of the timber.

Turning to the field experiments, the results of those carried out according to the Forest Research Institute Scheme have to date given satisfactory results as, with the exception of a few soft-wood sleepers laid down in Burma and on the Eastern Bengal Railway, none have been damaged by white-ants. The only note of warning comes from the

experiments in progress on the Idar-Brahmakhed Extension of the Bombay, Baroda and Central India Railway, where up to 10 per cent. of the *Red Sarayah* sleepers have had recently to be removed, owing to damage by white-ants and to splitting. From the report it appears that the attack is not superficial but that the interior of the sleepers has been attacked. This clearly denotes two facts, *i.e.*, that the treatment still holds good on the surface of the timber and that the antiseptic solution did not penetrate sufficiently deep into the timber. These facts do not necessarily tend to condemn the process but point to the fact that either the treatment was not carried far enough or that *Red Sarayah* does not lend itself readily to treatment unless pressure is applied. The writer is not prepared to accept the sweeping statement made by the inspecting officer that " at least after a period of over six years, the process does not cause timber to be immune from attacks of white-ants," and this for the reason that the Powellized sleepers in many other localities, after nearly the same period, show no signs of white-ant attack.

The next few years should definitely settle the question whether this process is suitable for treating Indian timbers, laid down in the varying climates of this country, while from the results obtained to date it is evident that the process must be combined with more careful methods of seasoning the timber.

In making the above statement, full consideration has been given to the fact that some of the Powellized sleepers laid down in Burma have failed within 8 years and that 10 per cent. of the *Red Sarayah* sleepers have had to be removed due to white-ant attack; on the other hand, the results so far obtained with the *Powellized Pinus longifolia* and *P. excelsa* sleepers, both perishable timbers in an untreated state, are distinctly encouraging.

(7) Field Experiments carried out with *Avenarius Carbolineum* oil.

(*i*) ARRANGEMENTS MADE TO CARRY OUT THE EXPERIMENTS AND THE NUMBER OF SLEEPERS TREATED.

The lines on which this group of experiments were carried out were entirely different from those of the *Powellizing* experiments. In this instance, the whole work was carried out by the Forest Department: the Forest Officers in the various provinces supplying the timber free, while the cost of extraction, conversion and treatment was borne by the Forest Research Institute. The *Terminalia tomentosa* sleepers were treated by Mr. Copleston, Divisional Forest Officer, North Division,

Kanara, the *Dipterocarp* sleepers by Messrs. Leete, Marsden and Hefferman, all Burma Foresters, and the *Pines* by the writer. The sleepers after treatment were handed over to the Railway Authorities, free of cost, as in the case of the *Powellized* sleepers.

The number of treated sleepers actually handed over to the Railways amounted to 326 B.G. *Pinus longifolia*, 400 B.G. *P. excelsa* treated at Jagadhri on the North-Western Railway, 400 M.G. *Dipterocarpus tuberculatus*, and 400 *D. alatus* treated at Pyinmana, on the Burma Railways, and 395 M.G. *Terminalia tomentosa* treated at Tavargatti, on the Madras and Southern Mahratta Railway, in all 1,921 sleepers.

(*ii*) METHOD OF TREATMENT.

(*a*) *Treatment of* Pinus longifolia *and* P. excelsa *broad gauge sleepers.*

The Pine sleepers were treated at Jagadhri by the writer in April 1912, in a 11′ 3″×3′ 9″×2′ 10″ open tank, sunk in a pit nearly flush with the ground. Beneath, a brick flue was constructed, running the whole length of the tank and open at both ends. Over the tank, an 8 feet tripod was erected, to the head of which was fixed a system of pulleys, the lower pulley being fitted with a stout hook. Two pairs of parallel sleepers were placed on each side of the tank and at right angles to it, to receive the sleepers. The sleepers were made up into parcels of six, with strips of iron between each sleeper and the whole bound together with iron slings, fitted with hooks and eyes. On the first parcel being made up, the centre sling was passed over the pulley hook and the load hoisted into the tank. A second parcel was then made up and hoisted on to the top of the first load, effectually submerging it in the oil, the second load being submerged by adding additional sleepers. After immersion for the required period, the weights were removed and the two batches of treated sleepers slung, after the oil had been allowed to drip off, to the opposite side and eventually removed to the stacking yard.

It was found that by allowing a 15 minutes immersion period, 5 minutes for the oil to drip off the sleepers and 15 minutes for stacking and changing them, that 12 sleepers could be treated in 35 minutes.

With a view of ascertaining the period of immersion required in order to make *Pinus longifolia* and *P. excelsa* broad gauge sleepers absorb 3 lbs. of oil each, six sleepers of each species were weighed before and

PLATE VI.

again after a 10 minutes immersion period. The results are shown below :—

TABLE XI.

Pinus longifolia.			Pinus excelsa.	
Number of sleepers.	Weight before immersion, in lbs.	Weight after immersion, in lbs.	Weight before immersion, in lbs.	Weight after immersion in lbs.
6	855¾	895¾	683	699

The *Pinus longifolia* sleepers absorbed 40 lbs., and the *Pinus ex.* sleepers 16 lbs. In order to make each species absorb approximately 3 lbs. each, the period of immersion for *Pinus longifolia* was reduced to 5 minutes and that of *Pinus excelsa* increased to 15 minutes. By treating the two species of Pine timber in this way, 726 *Pinus longifolia* and *P. excelsa* sleepers absorbed 2,789 lbs. or 3·84 lbs. of oil per sleeper. The penetration of the oil into the timber varied according to whether the sleeper contained sap-wood or not, the average depth into the heart-wood of *Pinus longifolia* being ½″ to ¾″ at the ends and half that on the sides while, in the case of *Pinus excelsa*, it rarely exceeded ½″ at the ends and ¼″ on the sides. The temperature of the oil was raised to 80°C. for *Pinus excelsa*, and to 50°C. for *Pinus longifolia* as, at that stage of the experiments, it was thought that any tempera[illegible] r 50°C. for the latter species would cause the timber to crack. Further experiments have shown that it is possible to raise the temperature to 85°C. or 90°C. without damaging this species of timber.

(*b*) *Treatment of* Dipterocarpus tuberculatus *and* D. alatus *metre-gauge sleepers.*

The Dipterocarp sleepers were treated in 1912 by Mr. Leete, Divisional Forest Officer, Pyinmana, with the help of Mr. Marsden, the Director of the Burma Forest School, and Mr. Hefferman, Extra-Deputy Conservator of Forests. The plant used consisted of 4 small tanks made of galvanized iron sheeting, two of which take 5 and two 6 metre-gauge sleepers at a time. The tanks in which the experiments were carried out are embedded in masonry to within a couple of inches from the top and fitted with brick fire-places and flues running beneath them. They are laid parallel to each other about 8 feet apart, from centre to centre. Along each end of the tanks are two rails, supported on posts about 3 feet

6 inches high, from the ground, on which slides a beam at right angles to the rails and therefore parallel to and above the tanks, filled with flat iron plates. To the centre of the beam are attached two simple wooden pulleys, about 3 feet apart ; to raise a parcel of sleepers, two ropes, one over each pulley, are hooked to the chains round the sleepers, and as the parcel of sleepers is raised out of the tank, two small poles or bars are put at right angles across the tank and the parcel allowed to rest on them until it is broken up and the sleepers removed. In the same way the sleepers to be treated are made up into lots over the tank, then bound and lowered into the solution. After having dealt with the sleepers for one tank, the bar is pushed over the next tank and the same operation repeated.

Such a type of plant is very convenient for treating a few sleepers for experimental purposes. With an immersion period of, say, ten hours, the four small tanks can deal with about 48 sleepers a day or 1,200 a month. Were the work to be carried out on a larger scale, it would be necessary to raise the travelling bar to 5 feet above the ground in order to permit of differential, instead of simple pulleys, being used and to have larger tanks of, say, 6 feet 4 inches long by 5 feet broad and 2 feet 8 inches deep, taking two parcels of 9 sleepers each or 18 per tank.

Working with an immersion period of 10 hours and with 10 tanks in use, the number of sleepers which could be dealt with daily would amount to 360, say, 9,000 a month or 100,000 sleepers a year.

The difficulty experienced in sinking the Pine sleepers was not experienced when dealing with the *Dip'erocarp* sleepers, as their specific gravity is higher than that of the Pine woods, so that a bit of old rail was found to be quite sufficient for the purpose.

The treatment of the sleepers was carried out as follows :—

As soon as the oil reached a temperature of about 70°C., the sleepers were put in and allowed to remain in the hot oil at a temperature varying from 75°C. to 90°C. for an hour. At the end of that time the fires were drawn and the sleepers allowed to remain in the oil for another hour while the liquid cooled down. As the work of treating the sleepers was in progress, a number of sleepers were weighed before and after treatment with the result that 72 *Dipterocarpus alatus* and 168 *D. tuberculatus* metre-gauge sleepers absorbed 1·11 lbs. of the oil each. It is probable that this is not a sufficient quantity of oil to protect the timber, so that a longer period of soaking would have been advisable. In order to ascertain the quantity of oil this species of timber will absorb, 4 sleepers were treated for an hour in the hot oil and then allowed to remain in the oil for 19 hours as it cooled down. These sleepers absorbed 9·4 lbs. each or, roughly, 6 lbs. per cubic foot.

(*c*) *Treatment of* Terminalia tomentosa *metre-gauge sleepers.*

No record is available as to the way in which these sleepers were treated. All that is known is that they were treated with hot *Avenarius Carbolineum* oil under the direction of Mr. Copleston, Divisional Forest Officer, North Division, Kanara, Bombay Presidency.

(*iii*) COST OF TREATMENT.

(*a*) *Cost of treating 326* Pinus longifolia *and 400* P. excelsa *broad gauge sleepers.*

The cost of landing treated sleepers on a railway depends on the locality from which they are obtained, the labour market, the amount of oil absorbed by the timber, its cost, the facilities for handling the sleepers and the cost of the plant. It follows that the cost will vary from locality to locality, so that the figures given below are only applicable to the place at which the experiment was carried out. Royalty charges on the timber are excluded from the calculations, the figures are actuals, except that the cost of slotting, numbering and similar charges, which only occur in experimental work, have been omitted, while 5 per cent. of the cost of the plant has been included.

		Rs.	A.	P.
1.	Cost of felling and converting 726 *Pinus longifolia* and *P. excelsa* broad gauge sleepers	786	0	0
2.	Cost of rafting the above to Jagadhri	86	0	0
3.	Cost of 2,789 lbs. of *Avenarius Carbolineum* oil	403	0	0
	Cost of freight on above oil	34	0	0
4.	Coolie wages for handling and treating sleepers	45	0	0
5.	5 per cent. on Rs. 331, the cost of tank	17	0	0
6.	5 per cent. on Rs. 100, cost of ropes, pulleys, etc.	5	0	0
7.	Miscellaneous charges for fuel, etc.	5	0	0
8	To 10 per cent. loss of oil due to leakage, evaporation, etc.	40	0	0
	TOTAL	1,421	0	0

From the above figures it will be seen that the cost of landing a treated broad gauge Pine sleeper on rail, containing 3·84 lbs. of *Avenarius Carbolineum* oil, amounts to Re. 1-15-6, of which the cost of treatment comes to 12 annas per sleeper. *Pinus longifolia* broad gauge sleepers can be purchased at Jagadhri in large numbers for Rs. 3-0-0 each; adding 12 annas for treatment and 4 annas profit for doing so, the cost of delivering treated sleepers on rail, working on a commercial scale, comes to Rs. 4-0-0 per sleeper. Even taking into consideration the high grade quality of *Avenarius Carbolineum* oil, 3·8 lbs. per sleeper is an extremely small amount of oil to effectively protect the timber, so that it would, in

all probabilities, be financially sound to add another 8·2 lbs., or a total of 12 lbs. of oil, and thus raise the price of the treated sleeper to Rs. 5-4-6.

As regards *Pinus excelsa* sleepers, their market value is from Rs. 3-8-0 to Rs. 4-0-0 each at Jagadhri, at which price they find a ready sale, so it follows that to treat this species of timber is hardly profitable.

(*b*) *Cost of treating 400* Dipterocarpus tuberculatus *and 400* D. alatus *metre-gauge sleepers.*

As has been stated elsewhere, some of the Dipterocarp broad gauge sleepers destined to be Powellized were not utilized for that purpose; they were, therefore, converted into metre-gauge size for this experiment. The number was, however, insufficient; so metre-gauge sleepers were cut direct from the logs to make up the deficit. In the following calculations, the cost throughout has been assumed to be that of cutting direct from the log into metre-gauge size, otherwise the figure arrived at would be entirely misleading.

	Rs.	A.	P.
1. Cost of felling, conversion and extraction of 400 *Dipterocarpus tuberculatus* metre-gauge sleepers .	450	0	0
2. Cost of felling, conversion and extraction of 400 *Dipterocarpus alatus* metre-gauge sleepers . .	400	0	0
3. For spreading, stacking and sorting in Depôt . .	46	0	0
4. Cost of 80 gallons of oil to treat 800 sleepers with 1·11 lbs. of oil	130	0	0
5. Freight on oil	32	0	0
6. Coolies' wages for handling and treating sleepers .	41	0	0
7. 5 per cent. of cost of plant	44	0	0
8. Fuel	89	0	0
9. Miscellaneous charges	13	0	0
10. 10 per cent. less oil lost by evaporation, drip, etc. .	13	0	0
TOTAL .	1,258	0	0

The cost of landing a treated *Dipterocarp* metre-gauge sleeper on rail amounts to Re. 1-9-2, exclusive of royalty on the timber or on treatment, and this with only 1·1 lbs. of the oil to protect the timber. From experience gained since these experiments were carried out, it is considered that 1·1 lbs. of oil is quite inadequate to protect the timber for any length of time; to make the process effective the amount of oil will have to be increased to at least 9 lbs. per metre-gauge sleeper or 6 lbs. per cubic foot. This could not be done with *Avenarius Carbolineum* oil alone, as the cost would be prohibitive. A means of cheapening the oil would have to be found as, for instance, by mixing it with a cheaper solution such as *Burma Earth oil.* How long 1·1 lbs. of the oil will protect the sleepers will be demonstrated by the sleepers so treated and now in the line.

(*c*) *Cost of treating 400* Terminalia tomentosa *metre-gauge sleepers.*

No detailed figures were kept as to the cost of treating these sleepers, though the total cost for each operation is available :—

	Rs.	A.	P
Felling and extraction	300	0	0
Cost of conversion	400	0	0
Cost of oil	226	0	0
5 per cent. on cost of plant	10	0	0
TOTAL	936	0	0

The cost of treating a metre-gauge *Terminalia tomentosa* sleeper comes to Rs. 2-5-5, exclusive of royalty on the timber.

(*iv*) NOTES ON THE BEHAVIOUR OF SLEEPERS TREATED WITH *Avenarius Carbolineum* OIL, AFTER HAVING BEEN LAID IN THE LINE.

The sleepers were handed over to and laid down by the Railway Authorities from 2½ to 3½ years ago, so that an insufficient period of time has elapsed to enable definite conclusions being drawn from these experiments. The results are, however, of sufficient interest to justify their being recorded, while by doing so the conditions under which, and localities where, these sleepers have been laid down are placed on record.

TABLE XII.

Record of sleepers treated with Avenarius Carbolineum *oil and laid for experimental purposes in different sections of the line.*

Species.	Number of sleepers laid down.	Locality where laid down.	Date of laying in the line.	Date of last inspection.	Inspection notes.	REMARKS.
		North-Western Railway, Saharanpur District.				
Pinus excelsa (Kail).	400 B. G.	Mile 12/14 to 12/20. Between Muradnagar and Begumabad, 3 miles from latter.	11th July 1913	21st December 1915.	One sleeper badly cracked due to original fault, eleven sleepers developing cracks, rest in good condition. No signs of white-ant attack. (Inspected by Executive Engineer and Forest Economist.)	Marked A. C. KAIL. Numbered 1601 to 2000 on zinc plates.
Pinus longifolia (Chir)	326 B G.	Mile 12/5 to 12/6. Between Muradnagar and Begumabad, 3 miles from latter.	25th July 1913	Ditto	Three sleepers are cracked, due to their having been cut so as to include the heart of the tree. A few show signs of warping which, judging from the adzing to receive the rail, must have occurred before they were laid in the line. They were nearly all laid "heart up," which has given better results than when laid "heart down," as was the case with those laid in the line near Lhaksar. Up to date they compare favourably with the treated *Pinus excelsa* sleepers, of which the record is given above. (Inspected by Executive Engineer and Forest Economist).	Marked A. C. CHIR. Numbered 1201 to 1526, on zinc plates.
Dipterocarpus tuberculatus (In)	134 M. G.	At Pyinmana. Mile 225/7 to 225/8½. Rangoon-Mandalay Main line, Burma Railways.	21st December 1912.	3rd June 1916.	Seven are quite rotten and must be removed. Others fairly good, rather cracked, a few beginning to rot. (Inspected by Mr. A. Rodger and Assistant Engineer, Yamethin.)	Marked 'D T'—A. C. 201-334.

Ditto	133 M. G. .	Between Myitnge and Tagundaing. Mile 378/12½ to 378/14. Upper Burma.	8th December 1912.	30th January 1915.	The following number of sleepers, out of a total of 133, were found to be defective— Slightly cracked . . 6 ,, warped . . 10 ,, cracked and warped 4 Deeply cracked . . 0 Decaying . . . 1 TOTAL . 21 (Inspected by the Deputy Conservator of Forests, Mandalay.)	Marked 'D T.'
Ditto	133 M. G. .	Just south of Maymyo on the Lashio line. Mile 421/12 to 421/15½. Burma Railways.	25th January 1913.	2nd February 1915.	The following number of sleepers, out of a total of 133, were found to be defective— Slightly cracked . . 9 ,, warped . . 7 ,, cracked and warped 4 Deeply cracked . . 6 TOTAL 26 (Inspected by the Deputy Conservator of Forests, Mandalay.)	Marked 'D T.'
Dipterocarpus alatus (Kanyin).	134 M. G. .	At Pyinmana. Mile 225/10 to 225/12½. Rangoon-Mandalay Main line, Burma Railways.	21st December 1912.	3rd June 1916	Seven are quite rotten and must be removed. Others fairly good, rather cracked, a few beginning to rot. None to be removed. (Inspected by Mr. A. Rodger and Assistant Engineer, Yamethin.)	Marked 'D A.'
Ditto	133 M. G. .	Between Myitnge and Tagundaing. Mile 378/10 to 378/11½. Upper Burma.	6th December 1912.	30th January 1915.	Out of 133 sleepers laid down, the following were found to be defective— Slightly cracked . . 15 ,, warped . . 14 Cracked and warped . 6 Deeply cracked . . 1 TOTAL . 36 (Inspected by Deputy Conservator of Forests, Mandalay.)	Marked 'D A.'

Record of sleepers treated with Avenarius Carbolineum *oil and laid for experimental purposes in different sections of the line*—contd.

Species.	Number of sleepers laid down.	Locality where laid down	Date of laying in the line.	Date of last inspection.	Inspection notes.	REMARKS.
Dipterocarpus alatus (Kanyin).	133 M. G.	Just south of Maymyo on Lashio line. Mile 421/15½ to 421/17½, Burma Railways.	25th January 1913.	2nd February 1915.	Out of 133 sleepers laid down, the following were found to be defective— Slightly cracked . . 4 ,, warped . . 1 Cracked and warped . . 1 Deeply cracked . . 6 TOTAL 12 (Inspected by Deputy Conservator of Forests, Mandalay.)	Marked 'D A.'
Terminalia tomentosa (Sain.)	100	Between Aliganj and Kashipur. Mile 30/7 to 30/8, Rohilkund and Kumaon Railway.	28th June 1913 .	26th January 1917.	The sleepers are serving well but there are 13 per cent. badly and 10 per cent. slightly cracked. (Inspected by the Sub-Divisional officer, Kashipur, Rohilkhund and Kumaon Railway.)	Without bearing plates. Branded A. C. 13.
Ditto	195	Between Bhojeepura Junction and Izatnagar. Mile 193 to 193/4. Rohilkund and Kumaon Railway.	4th August 1913.	26th February 1917.	The sleepers are in good condition and the gauge is keeping well at present. No particular cracks appear to be developing. (Inspected by Assistant Engineer, Bareilly Sub-Division, Rohilkund and Kumaon Railway.)	Ditto
Ditto	100	Between Sitapur and Jharekapur. Mile 55/13 to 55/14. Rohilkund and Kumaon Railway.	8th August 1913.	7th December 1916.	About 9 per cent. of the sleepers are badly cracked and 11 per cent. slightly cracked. All the sleepers are still serviceable. (Inspected by the Assistant Engineer, Sitapur, Rohilkund and Kumaon Railway.)	Ditto

v) GENERAL CONCLUSIONS BASED ON THE RESULTS OF EXPERIMENTS WITH SLEEPERS TREATED WITH *Avenarius Carbolineum* OIL.

It is not possible to judge from the results obtained as to the value of this oil for preserving sleepers, as the oldest experiments have only been in progress 3½ years. The results to date are quite favourable, especially with the Pine sleepers, the timber of which, in an untreated state, is more perishable than that of the *Dipterocarps* and *Terminalia tomentosa.* Whether the small amount of oil put into these sleepers is sufficient to protect them for a reasonable period of time is somewhat doubtful. At the time these experiments were carried out, every attempt was made to keep the cost of treatment as low as possible, though it would probably have been advisable to raise the cost of treatment by allowing a greater absorption of oil or to have reduced the cost of the solution by adding a cheaper grade of oil and thus making it possible to introduce more oil into the timber, without unduly raising the cost of treatment.

In any case, these experiments will be of considerable value, as several of the more recent experiments have been carried out with far larger quantities of good grade creosote oils, which should yield valuable results as to the relative merits of light and heavy impregnation.

8. Field Experiments carried out with *Chloride of Zinc* and either *Green oil* or *Avenarius Carbolineum* and a few sleepers treated with *Atlas* solution and *Green oil*.

(i) ARRANGEMENTS MADE TO CARRY OUT THE EXPERIMENTS AND THE NUMBER OF SLEEPERS TREATED.

The arrangements made for treating these sleepers were the same as in the case of the sleepers treated with *Avenarius Carbolineum* oil, with the exception that the *Terminalia tomentosa* sleepers were obtained from the Betul Division of the Berar Circle, Central Provinces, instead of from the Kanara Division in Bombay.

The number of treated sleepers actually handed over to the Railways amounted to 100 *P. longifolia* and 100 *P. excelsa* broad gauge sleepers, treated at Jagadhri, North-Western Railway; 438 *Dipterocarpus tuberculatus* and 437 *D. alatus,* metre-gauge sleepers, treated at Pyinmana, Burma Railways; and 293 *Terminalia tomentosa* broad gauge sleepers, treated at Shahpur, Betul District, Central Provinces. These sleepers, amounting to 1,368 in all, were treated by the writer during the touring season of 1912-13.

The plant used to treat the Pine and *Terminalia tomentosa* sleepers was the same as that used for treating the timber with *Avenarius Carbolineum,* while the *Dipterocarp* sleepers were treated in the Pyinmana plant, details of which are given on page 37.

(*ii*) METHOD OF TREATMENT WITH CHLORIDE OF ZINC AND GREEN OIL.

(*a*) *Treatment of* Pinus longifolia *and* P. excelsa *broad gauge sleepers.*

The Pine sleepers with which this experiment was carried out were all well-seasoned, having been prepared in the hills a full year before treatment. After conversion they were floated down the Tons River to Dhakpathar Depôt, from there brought down the canal to Jagadhri and allowed to season for a further period of 2 or 3 months in the Depôt.

The method of treatment consisted in soaking the sleepers in a 2 per cent. solution of *Chloride of Zinc,* heated to a little over 50°C. for 2 hours, and then allowing them to remain in the solution while it cooled down for a further period of 10 hours. After having allowed the sleepers to dry thoroughly for 10 to 14 days, they were plunged into a hot bath of *Green oil* for 3 to 5 minutes and then removed.

To ascertain the correct period of immersion necessary to make the sleepers take up 15 lbs. of the *Chloride of Zinc* solution, 10 per cent. of the sleepers were given varying periods of immersion, and weighed before and after treatment. Table XIII demonstrates the results obtained :—

TABLE XIII.

Species.	Average absorption per sleeper, of 6 sleepers, in lbs.	Temperature of the *Chloride of Zinc* solution.	Period of immersion.
	lbs.		
Pinus longifolia .	5·5	55°C.	Half hour.
Ditto .	9·8	55°C.	2½ hours.
Ditto .	8·5	60°C.	3 ,,
Ditto .	10·8	71°C.	3 ,,
Ditto .	12·3	67°C	2 hours heating and 10 hours to cool down.
Ditto .	20·0	70°C.	Ditto
	Average 16·1 lbs. absorption after 12 hours immersion.		
	lbs.		
Pinus excelsa .	8	85°C. dropping to 56°C.	Heated for 6 hours and allowed to cool for 6 hours.
Ditto .	20·1	70°C.	Ditto
Ditto .	13·5	70°C.	Ditto
	Average 13·9 lbs. after 12 hours immersion.		

The above figures denote considerable variations in absorption, due chiefly to the amount of sap-wood present in different sleepers and to the differences in density of the timber of individual sleepers. It was found that the average amount of the solution taken up by the *Pinus longifolia* sleepers was 16 lbs. and that of the *Pinus excelsa* sleepers to be 14 lbs. which, together with the oil treatment, is considered sufficient to protect the timber.

The sleepers, after treatment in the salt, were allowed about a fortnight in which to dry, this period being considered sufficient, as at the time of treatment the temperature at Jagadhri stood well over 110°F. in the day, while the hot winds materially hastened the process of drying. The oil bath, to which the sleepers were then subjected, was limited to a 3 to 5 minutes immersion, during which period the *Pinus longifolia* sleepers absorbed 4·4 lbs. and the *Pinus excelsa* 3·5 lbs. of *Green oil* per sleeper. The object of the coating of oil given to the sleepers was primarily to prevent the salt from leaching out of the timber by excessive moisture and also in a measure to preserve the timber.

(*b*) *Treatment of* Dipterocarpus tuberculatus *and* D. alatus *metre-gauge sleepers with* Chloride of Zinc *and* Green oil *and a few with* Atlas *solution and* Green oil.

The *Dipterocarp* metre-gauge sleepers were prepared from logs which had been seasoning for over a year, and were allowed to lie in the depôt for a further period of 2 or 3 months after conversion and before being treated.

The object aimed at in this set of experiments was to treat 700 metre-gauge sleepers with *Chloride of Zinc* and *Green oil* and 300 metre-gauge sleepers with *Atlas* and *Green oil.* The latter process was given a trial, but was abandoned after 30 sleepers had been treated, as it was soon found that working in open tanks, with native labour, the business was too dangerous owing to the high percentage of arsenic in the solution. The balance of the sleepers destined for this experiment were therefore treated with *Chloride of Zinc* and *Green oil.*

A 2 per cent. solution of *Chloride of Zinc* was adopted, and it was decided to try and make the sleepers take up 9 lbs. of the solution, that is, 6 lbs. per cubic foot. The sleepers after treatment in the salt, were allowed to dry thoroughly, a point of great importance and then immersed in *Green oil*

To ascertain the necessary period of immersion in order to make the sleepers take up 9 lbs. of oil each, a number were weighed before, and

after treatment in the *Chloride of Zinc* solution, heated from 60° to 70°C., with the following results :—

TABLE XIV.

Species.	Average absorption, per sleeper, of 5 sleepers.	Temperature of the *Chloride of Zinc* solution	Period of immersion.
	lbs.		
Dipterocarpus tuberculatus.	6·6	70°C.	4 hours in a solution raised to 70°C. and allowed to remain for 20 hours while it cooled down= 24 hours.
Ditto	5·2	Ditto	
Ditto	7·0	Ditto	
Ditto	7·3	Ditto	
Average	6·5 lbs. per sleeper.		
Dipterocarpus alatus	3·4	70°C.	2 hours heating and 6 hours cooling = 8 hours.
Ditto	6·8	Ditto	3 hours heating and 20 hours cooling = 23 hours.
Ditto	6·6	65°C.	$2\frac{1}{2}$ hours heating and 19 hours cooling = $21\frac{1}{2}$ hours.
Ditto	7·9	Ditto	3 hours heating and 19 hours cooling = 22 hours.
Ditto	15·2	60°C.	5 hours heating and $15\frac{3}{4}$ hours cooling = $20\frac{3}{4}$ hours.
Ditto	9·8	60° to 70°C.	4 hours heating and 20 hours cooling = 24 hours.
Ditto	13·1	Ditto	Ditto
Ditto	6·2	Ditto	1 hour heating and 23 hours cooling = 24 hours.
Ditto	8·2	Ditto	Ditto
Ditto	7·5	Ditto	Ditto
Ditto	7·8	Ditto	Ditto
Ditto	6·8	80°C.	1 hour heating and then transferred to another tank of cold oil for 23 hours = 24 hours.

Average absorption per sleeper when immersed for 24 hours= 8·1 lbs.

As in the case of the Pine sleepers, the absorption varied with different batches treated though, on the whole, the amounts taken up were more

uniform than was the case with the conifer timber. The reason for these variations is that no two pieces of timber have the same density or contain the same amount of moisture and resin. The presence of sap-wood is also a powerful factor governing absorption, though in this instance inapplicable, as the sleepers were all cut from heart-wood.

That absorption is directly proportionate to the time of immersion is shown by the 'Kanyin' sleepers, which were immersed for 8 hours and took up 3·4 lbs. each, while those immersed for 24 hours took up an average of 8·1 lbs. Heating the solution also has a striking effect on absorption: twenty-two sleepers were immersed for 24 hours in a cold solution and only took up 3·3 lbs. each, whereas a batch put into a solution raised to 80°C. for 1 hour and then quickly transferred to a cold bath for 23 hours absorbed 6·8 lbs. each. The reason for this is obvious and is the basis on which certain timbers can be treated by the Open Tank method, *i.e.*, that by placing the timber in a hot solution, the air in the timber expands and is driven out and as the wood also expands a small quantity of moisture is also expelled. As the whole cools down, the timber being immersed, instead of again absorbing air, absorbs the solution in which it finds itself. The actual period of heating does not exercise so great an influence on the absorption as the amount of drop in temperature after heating.

After the sleepers had had time to dry thoroughly, they were again immersed—this time in a bath of *Green oil* heated to 50°C. for 5 minutes—during which time each sleeper absorbed 1·1 lb. of oil, thus completing the treatment according to this process.

(c) *Treatment of* Terminalia tomentosa *broad gauge sleepers with* Chloride of Zinc *and* Avenarius Carbolineum *oil.*

The sleepers with which this experiment was carried out were prepared in the Betul District, Berar Circle, Central Provinces, and were treated by the writer in March 1913, in a locally prepared tank, similar to that used at Jagadhri on the North-Western Railway. The 300 broad gauge sleepers to be treated were prepared from trees felled in December 1912 and converted in January and February 1913 and were therefore not thoroughly seasoned. This was unavoidable though to be regretted; while, owing to the fact that this species does not attain a large size in the locality, the sleepers contained a large percentage of sap-wood and were not, taking them altogether, of a very high class. The fact that these sleepers contained sap-wood, is not a drawback, as the sap-wood is hard and, if properly impregnated, is probably as durable as the heart-wood.

The object aimed at was to impregnate the sleepers with from 9 to 12 lbs. of a 2 per cent. solution of *Chloride of Zinc* and to coat them with *Avenarius Carbolineum* oil, having given them time to dry after immersion in the salt solution, the oil treatment being carried out to fix the salt and to preserve the timber.

To ascertain the necessary period of immersion required in order to make the sleepers absorb 12 lbs. of the *Chloride of Zinc* solution, a certain number of sleepers were weighed before and after treatment, with the following results :—

TABLE XV.

Species.	Average absorption, per sleeper, of 15 sleepers.	Temperature of *Chloride of Zinc* solution.	Period of immersion.
	lbs.		
Terminalia tomentosa.	11·4	75°C.	3 hours heating and 18½ hours cooling = 21½ hours.
Ditto	8·5	60°C.	3 hours heating and 21 hours cooling = 24 hours.
Ditto	12·26	79°C.	5 hours heating and 19 hours cooling = 24 hours.
Ditto	13·46	80°C.	Ditto

After having ascertained that it took 5 hours heating to 80°C. and 19 hours cooling, or 24 hours in all, to make the sleepers take up 12 lbs. each, the rest of the sleepers were treated on the same lines.

It was, in a way, gratifying to have found it possible to make so hard a wood as that of *Terminalia tomentosa* take up the required amount in 24 hours, as some difficulty was anticipated in doing so when working with open tanks.

In order to ascertain the time required for the sleepers to regain their natural weight, after having been treated in the salt solution, a number were weighed directly after being withdrawn from the treating tank and again seven days later. The total weight of 15 sleepers was 3,381 lbs. before immersion, 3,551 lbs. after immersion and 3,384 lbs. seven days later. The sleepers had, therefore, practically regained their normal weight within 7 days ; in fact, some were actually lighter than before immersion though, as some were over weight at that time, they were all allowed to dry for a further period of seven days to ensure complete dryness before subjecting them to an oil bath.

The sleepers were then treated in a hot bath of *Avenarius Carbolineum* oil, selected batches of which gave the following results :—

TABLE XVI.

Species.	Average absorption, per sleeper, of 3 sleepers.	Temperature of *Avenarius Carbolineum* oil.	Period of immersion.
	lbs.		
Terminalia tomentosa	2·8	52°C.	10 minutes.
Ditto	3·8	54°C.	8 "
Ditto	2·8	62°C.	5 "
Ditto	3·8	46°C.	5 "
Ditto	2·8	50°C.	3 "
Ditto	3·6	55°C.	2 "
Ditto	2·5	38°C.	Simply dipped in and taken out again.
Ditto	3·3	40°C.	Ditto
Ditto	2·6	40°C.	Ditto

It is clear from the above figures that the result of either dipping in the sleepers and pulling them out again at once or immersing them for upwards of 10 minutes, when dealing with a close-grained timber such as *Terminalia tomentosa*, gives the same results.

This is as might be expected, as the oil in any case could only affect the outer edge of the tissue and fill up the small cracks, not having time to sink deep into the tissue itself. It remains to be seen whether so slight an impregnation of oil will be sufficient to prevent the *Chloride of Zinc* from being leached out of the timber.

Before leaving this group of experiments, it is necessary to record a point of some interest in connection with the rate of absorption of the oil. It was found that, when treating the *Terminalia* and *Dipterocarp* sleepers, the oil was absorbed by the timber much more readily when the sleepers had been originally treated in *Chloride of Zinc* for 24 hours than when no such previous treatment had taken place. The reason for this is no doubt that as the timber had been subjected to a water bath and also a good deal of the sap had been expelled by expansion of the timber due to heating, the surface of the wood and the outer intercellular spaces were clean ; in other words, the outer tissue being porous it was in the best possible state to take up the solution. It follows, therefore, that if difficulty is found in making a dense timber absorb sufficient antiseptic, it should either be immersed in a hot bath or placed in a running stream of water for two or three weeks, and then allowed to dry thoroughly before treatment.

(*iii*) Cost of treating sleepers with *Chloride of Zinc* and either *Green oil* or *Avenarius Carbolineum oil.*

Before considering the cost of treating each different species of timber and in order to clearly define the basis on which the calculations are made, it is necessary to state that the railway freight entered is that which was actually incurred on the whole consignments of both salt and oil, as it has not been found possible to split up the sum in proportion to the amount of antiseptic absorbed by the sleepers and that left over after treatment. In any case the amount was insignificant and would hardly affect the price when worked out to cost per sleeper. The cost of the oil is put at 6 annas 10 pies per gallon, which was the actual price paid; if purchased in bulk the price may be reduced, while the inclusion of the price of oil needed to flood the sleepers can hardly be considered a necessary item of expenditure, and has only been added to form a liberal estimate. And lastly, the labour bills must be considered as excessive, as the coolies were new to the work, while they also include the labour expended on erection of plant. Taking the above points into consideration, the cost of treatment works out as follows :—

(*a*) *Cost of treating 100* Pinus longifolia *and 100* P. excelsa *broad gauge sleepers, with* Chloride of Zinc *and* Green oil.

The Pine sleepers utilized in this experiment were supplied by the Chakrata Division, as were also those used in the *Avenarius Carbolineum* experiments. They were sound, well-seasoned sleepers, containing little twisted fibre though, in some cases, having been cut including the core of the tree. The figures given below do not include either royalty on the timber or on the treatment :—

	Rs.	A.	P.
Cost of felling, conversion and extraction from forests to Jagadhri of 200 broad gauge Pine sleepers . .	232	0	0
Cost of *Chloride of Zinc* to treat 200 broad gauge sleepers, absorbing 15 lbs. of a 2 per cent. solution at 6 annas per lb. concentrated	22	0	0
Freight on the salt from Calcutta to Jagadhri . .	12	0	0
Cost of *Green oil* to treat 200 broad gauge sleepers, 4 lbs. per sleeper, at 6 annas 10 pies per gallon . . .	34	0	0
Freight on *Green oil* from Antwerp to Jagadhri, inclusive of oil required to flood them in tank . . .	75	0	0
Labour for treating, stacking, spreading, etc.. . .	38	0	0
5 per cent. of cost of plant	22	0	0
Fuel	4	0	0
10 per cent., due to evaporation and leakage of oil . .	2	0	0
Miscellaneous charges	8	0	0
Total .	449	0	0

The cost of treating a Pine sleeper and delivering it on rail at Jagadhri, therefore, amounts to Rs. 2-3-11, exclusive of cost of timber. Working on a commercial basis, the cost works out as follows :—

Untreated *Pinus longifolia* broad gauge sleepers can be purchased at Jagadhri for Rs. 3-0-0 each. The cost of treating the sleeper comes to Re. 1-1-4; to this must be added royalty on treatment, say, 8 annas, or a total of Rs. 4-9-4 per treated broad gauge "Chir" sleeper. The case of the *Pinus excelsa* sleepers has been dealt with on page 40 and need not be again cited.

(*b*) *Cost of treating 438* Dipterocarpus tuberculatus *and 437* D. alatus *metre-gauge sleepers, with* Chloride of Zinc *and* Green oil.

	Rs.	A.	P.
Cost of felling, conversion and extraction of 875 metre-gauge sleepers at Re. 1-1-0 each	929	11	0
Cost of *Chloride of Zinc* to treat 875 metre-gauge sleepers, absorbing 9 lbs. each of a 2 per cent. solution, at 6 annas per lb., concentrated	59	0	0
Railway freight on the salt (concentrated)	6	0	0
Steamer freight on ditto ditto	5	0	0
Cost of *Green oil* to treat 875 metre-gauge sleepers, absorbing 1·1 lb. each, at 6 annas 10 pies per gallon	41	0	0
Freight on *Green oil* from Antwerp to Rangoon	50	0	0
Railway freight on oil from Rangoon to Pyinmana	18	8	0
Labour for treating and handling	15	8	0
5 per cent. on cost of plant	51	8	0
Cost of fuel	68	0	0
10 per cent., due to evaporation and leakage of oil	11	0	0
Miscellaneous charges	26	0	0
TOTAL	1,281	3	0

The depreciation and fuel charges are, without doubt, high and could be reduced, when working on a more extensive scale. The cost of delivering a metre-gauge *Dipterocarp* sleeper on rail comes to Re. 1-7-5, exclusive of royalty. The Burma Railways pay Re. 1-12-0 for a Pyinkado metre-gauge sleeper, so that to deliver a treated *Dipterocarp* sleeper, the operator would have to be content with 4 annas 7 pies royalty per sleeper, an extremely small profit. He probably gets less than that for his labour when dealing with a Pyinkado sleeper, hence the difficulty experienced in the past by the Railways to obtain all the sleepers they require. Until the price of sleeper woods goes up in Burma, which will probably be the case in the future, the business of treating sleepers in Burma must remain in abeyance.

(*c*) *Cost of treating 300* Terminalia tomentosa *broad gauge sleepers with* Chloride of Zinc *and* Avenarius Carbolineum.

	Rs.	A.	P.
Cost of felling, conversion, and extraction of 300 broad gauge sleepers	602	0	0
Cost of *Chloride of Zinc* to treat 300 broad gauge sleepers, absorbing 12 lbs. of a 2 per cent. solution, at 6 annas per lb. concentrated.	27	0	0
Railway freight and cart-hire on the salt	6	8	0
Cost of *Avenarius Carbolineum* oil, to treat 300 broad gauge sleepers, absorbing 3 lbs. per sleeper . .	163	0	0
Cost of railway freight and cart-hire on oil . . .	16	8	0
Labour, for handling, treating and stacking sleepers .	50	0	0
5 per cent. on cost of plant	17	8	0
Fuel	13	8	0
10 per cent., due to leakage and evaporation of oil, etc. .	16	0	0
TOTAL .	912	0	0

The cost per sleeper works out to Rs. 3-0-7. This is a high figure when compared with Pine sleepers treated in a similar way, but using *Green oil* instead of *Avenarius Carbolineum.* The reason is that the former oil costs 6 annas 10 pies, as against Rs. 2-0-0 per gallon ; while the cost of extraction was Re. 1-2-6 in the case of Pine sleepers, as against Rs. 2 of *Terminalia tomentosa* sleepers. It remains to be seen whether the use of the more expensive oil is justified by results. *Terminalia tomentosa* may be classed as just below a first class sleeper in an untreated state ; if, by treatment, its life can be extended to 12 years or more, it should fetch somewhere about Rs. 4-8-0 to Rs. 4-10-0 on the market. The question of treating it is therefore a commercial proposition, as it costs about Rs. 3-0-0 to exploit and treat a broad gauge sleeper, which should leave a margin of profit for royalty and treatment in the neighbourhood of Re. 1-8-0.

(*iv*) NOTES ON THE BEHAVIOUR OF SLEEPERS TREATED WITH *Chloride of Zinc* AND EITHER *Green oil* OR *Avenarius Carbolineum,* AFTER HAVING BEEN LAID IN THE LINE.

The sleepers have been about 3 years in the line, so no definite results are as yet available. Their condition on the last date of inspection is recorded as below :—

TABLE XVII.

Record of sleepers treated with Chloride of Zinc *and* Green oil *or* Avenarius Carbolineum *and* Atlas *solution and* Green oil *and laid for experimental purposes in different sections of the line.*

Species.	Number of sleepers laid down.	Locality where laid down.	Date of laying in the line.	Date of inspection.	Inspection notes.	Remarks.
Pinus excelsa (Kail.)	100 broad gauge.	North-Western Railway, Saharanpur District. Mile 12/24 to 13/2. Between Muradnagar and Begamabad, 3 miles from latter.	4th August 1913.	21st December 1915.	No sleepers have been rejected up to date. In excellent condition, no signs of cutting under rail-seat, no signs of rot or white-ant attack. Practically all the sleepers laid heart up. (Inspected by Executive Engineer, Saharanpur, and Forest Economist.)	Marked $\frac{\text{C. Z.}}{\text{G. O.}}$ 'Kail.' Treated with *Chloride of Zinc* and *Green oil.*
Pinus longifolia (Chir.)	Do.	Mile 11/24 to 12/1. Between Muradnagar and Begamabad, 3 miles from latter.	3rd August 1913.	Do.	No sleepers have been rejected up to date. In excellent condition, no signs of cutting under rail-seat, no signs of rot or white-ant attack. Practically all the sleepers are laid heart up. (Inspected by Executive Engineer, Saharanpur, and Forest Economist.)	Marked $\frac{\text{C. Z.}}{\text{G. O.}}$ Chir. Treated with *Chloride of Zinc* and *Green oil.*
Terminalia tomentosa (Asain.)	293 broad-gauge.	Mile 516/10½ to 516/13½. Great Indian Peninsula Railway, Betul District.	October 1913	September 1916.	The sleepers are wearing satisfactorily, they are still quite sound and the chairs have not cut into the wood at all. (Inspected by the District Engineer, Jubbulpore).	Marked $\frac{\text{C. Z.}}{\text{A. C.}}$ and $\frac{\text{A. C.}}{\text{C. Z.}}$ Treated with *Chloride of Zinc* and *Avenarius Carbolineum oil.*
Dipterocarpus tuberculatus. (In.)	219 metre-gauge.	Near Pyinmana. Mile 224/13 to 224/15½. Burma Railways.	23rd July 1913.	3rd June 1916	Very good on the whole, slightly cracked but not rotten and none to be removed. Spikes holding, rails not eating in. (Inspected by A. Rodger, Esq., Forest Research Officer, Burma, and Assistant Engineer, Yamethin.)	Branded D. T. O. C. Z. Treated with *Chloride of Zinc* and *Green oil.*

TABLE XVII.

Recroıl of sleepers treated with Chloride of Zinc *and* Green oil *or* Avenarius Carbolineum *and* Atlas *solution and* Green oil *and laid for experimental purposes in different sections of the line*—continued.

Species.	Number of sleepers laid down.	Locality where laid down.	Date of laying in the line.	Date of inspection.	Inspection notes.	Remarks.
Dipterocarpus alatus (Kanyin.)	218 metre-gauge.	Near Pyinmana. Mile 224/9½ to 224/12. Burma Railways.	19th July 1913 .	3rd June 1916 .	Four are very rotten, attacked by white-ants and must be removed at once. Total found in the line 193; some are cracked and some are beginning to rot, but fairly good on the whole. Spikes holding well, and rails have not cut in badly. (Inspected by A. Rodger, Esq., Forest Research Officer, Burma and Assistant Engineer, Yamethin).	Branded D. A. / O / C. Z. Treated with *Chloride of Zinc* and *Green oil.*
Ditto .	198 metre-gauge.	Between Myitunge and Taguredaing, Mandalay District. Mile 378/15 to 17.	5th October 1913.	....	....	Branded D. A. C. Z. / G. O. Treated with *Chloride of Zinc* and *Green oil.*
Dipterocarpus tuberculatus. (In.)	218 metre-gauge.	Just north of Myingyan, Mandalay District. Mile 352/16 to 18.	25th October 1913.	....	....	Branded D T. C. Z. / G. O. Treated with *Chloride of Zinc* and *Green oil.*

(v) GENERAL CONCLUSIONS BASED ON THE RESULTS OF EXPERIMENTS WITH SLEEPERS TREATED WITH *Chloride of Zinc* AND EITHER *Green oil* OR *Avenarius Carbolineum.*

The primary object of these experiments was to compare the value of a mixed impregnation with the standard method of creosoting, by which some 8 lbs. per cubic foot of a good grade *Coal-tar creosote* are introduced into the timber, otherwise known as the "Fuel Cell" or "Straight method" of impregnation. When comparing the relative merits of the two processes, the most important factors to be considered are (*i*) durability and (*ii*) cost. With respect to these experiments, the durability of the timber cannot be determined for some years, while the cost has been fixed. Broad gauge *Pine* sleepers cost Re. 1-1-4, metre-gauge *Dipterocarp* sleepers cost Re. 0-6-0, and broad gauge *Terminalia tomentosa* sleepers Re. 1-0-0 to treat. *All creosote has to be imported into India, and costs somewhat about 12 annas per gallon, to land at any of the experimental stations; based on this figure, the estimated cost of treating a broad gauge sleeper by the "Full Cell" process is estimated at Rs. 2-4-0, or double the cost incurred when treating broad gauge sleepers by a mixed impregnation process with a salt and oil. Provided the durability tests with sleepers treated by a mixed impregnation method come up to expectation, it may prove to be one of those suitable for treating sleepers under Indian conditions.

9. Field Experiments carried out with Solignum and Burma oil or Liquid Fuel.

(*i*) ARRANGEMENTS MADE TO CARRY OUT THE EXPERIMENTS AND THE NUMBER OF SLEEPERS TREATED.

The fourth and last group of experiments to be carried out, according to the original scheme laid down for this enquiry, consisted in treating the five species of timber selected with a mixture of *Solignum* and *Earth oil*, the former a derivative of *Coal-tar creosote* and the latter of *petroleum* oil. *Solignum* is an expensive oil, though of established value for treating timber; a crude *petroleum* oil was added to it to cheapen the mixture, and thus permit a greater quantity of the solution being introduced into the timber.

The arrangements made to procure the sleepers, and the localities whence they were supplied were the same as those recorded in the previous experiments.

The *Pine* and *Terminalia tomentosa* sleepers were treated by the writer, and the *Dipterocarp* sleepers by Babu Gyan Singh, the writer's assistant.

* NOTE.—Since this was written there is every prospect of Coal-tar Creosote being available in the near future in India.

The number of sleepers handed over to the Railways, after treatment, was 249 broad gauge *Pinus longifolia* sleepers, 100 broad gauge *Pinus excelsa* sleepers, 460 broad gauge *Terminalia tomentosa* sleepers, 470 metre-gauge *Dipterocarpus tuberculatus* sleepers, and 500 metre-gauge *Dipterocarpus alatus* sleepers, in all 1,779 sleepers.

(*ii*) Method of treatment with *Solignum* and *Liquid Fuel.*

(*a*) *Treatment of* Pinus longifolia *and* P. excelsa *broad gauge sleepers and a special batch of* Cedrus Deodara *broad gauge sleepers.*

The aim of this experiment was to treat *Pine* sleepers in a mixture of 40 per cent. *Solignum* and 60 per cent. of *Earth oil.* The amount of oil it was proposed to introduce into each sleeper was 9 lbs., though, owing to some of the sleepers having seasoned in the yard a year longer than others, it was found difficult to keep the absorption constant. This difference was further accentuated by the presence of much sap-wood in some sleepers and little or none in others, necessitating their classification into two separate lots, and subjection to slightly different treatment.

A slight modification was made in the case of these experiments to the usual procedure followed in previous years, by treating 50 *Cedrus Deodara* sleepers, at the special request of the Railway Authorities, these sleepers being supplied free of cost.

In order to fix the immersion period for *Pinus longifolia* sleepers, the following tests were carried out :—

TABLE XVIII.

Species.	Average absorption, per sleeper, of 17 sleepers.	Temperature of *Solignum* and *Liquid Fuel.*	Period of immersion.
	lbs.		
Pinus longifolia, 4 weeks out of the floating stream, converted one year before treatment.	8·0	80°C. dropping to 55°C.	6 hours.
	6·5	81°C. „ 60°C.	4 „
	6·8	79°C. „ 68°C.	5 „
	7·2	80°C. „ 63°C.	6 „
	8·2	88°C. „ 66°C.	6 „
	8·5	93°C. „ 73°C.	6 „
Average of 102 broad gauge sleepers.	= 7·5		
Pinus longifolia, 8 to 12 months out of the floating stream, converted two years before treatment.	18·2	72°C. „ 56°C.	5 „
	27·7	70°C. „ 60°C.	4 „
	20·2	59°C. „ 57°C.	2 „
	8·7	62°C. „ 50°C.	1½ „
	10·7	59°C. „ 50°C.	1½ „
	6·8	48°C. „ 48°C.	20 minutes.
Average of 102 broad gauge sleepers.	= 15·4	....	

The remaining sleepers were treated by giving the former class 6 hours', and the latter 1 hour's immersion. It is noticeable that, when allowing the very dry sleepers more than 2 hours in a bath of oil, the amount of oil absorbed is not materially increased, which is no doubt due to the fact that the timber has reached its maximum power of absorption in Open Tanks, a state of affairs known as, "absorption to refusal."

Similar tests were carried out with the *Pinus excelsa* sleepers, which gave the following results :—

TABLE XIX.

Species.	Average absorption, per sleeper, of 17 sleepers in the 1st three lines, and of 8 sleepers in the 4th line.	Temperature of Solignum and Liquid Fuel oil.	Period of immersion.
	lbs.		
Pinus excelsa heart-wood sleepers, 10 to 12 months out of the floating stream, converted 2 years before treatment.	7·5	65°C. dropping to 39°C.	12½ hours.
	9·5	68°C. „ 45°C.	12 „
	9·8	74°C. „ 46°C.	12 „
	10·0	84°C. „ 52°C.	12 „
Average of 59 broad gauge sleepers.	= 9·2		
Pinus excelsa sap-wood sleepers, 10 to 12 months out of the floating stream, converted 2 years before treatment.	8·7	68°C. „ 55°C.	6 „
Pinus excelsa, a mixed lot of sap and heart-wood sleepers, 10 to 12 months out of the floating stream, converted 2 years before treatment.	17·7	73°C. „ 48°C.	9½ „

By treating heart-wood and sap-wood separately fairly regular results of absorption were obtained, the last batch of mixed heart and sap-wood gave most irregular results, the absorption by the latter being excessive and averaging double that of the former.

Fifty seasoned *Deodar* broad gauge sleepers were subjected to treatment with the following results :—

TABLE XX.

Species.	Average absorption, per sleeper, of two lots of 17 and one lot of 16 sleepers.	Temperature of *Solignum* and *Liquid Fuel* oil.	Period of immersion.
	lbs.		
Cedrus Deodara heart-wood sleepers.	3·6	74°C. dropping to 47°C.	14½ hours.
	6·4	83°C. „ 46°C.	24 „
	9·0	100°C. „ 51°C.	24 „

The results show that *Deodar* timber absorbs oil somewhat less readily than *Pinus longifolia* timber, were it desirable to introduce more than 9 lbs. of oil per broad gauge sleeper into *Deodar*, pressure would have to be resorted to. The experiments with *Deodar* were carried out at the instance of the Railway Engineers, but whether or not it would pay to treat this timber is a moot point, as treatment might increase the durability of the fibre beyond the mechanical life of the timber.

(*b*) *Treatment of* Dipterocarpus tuberculatus *and* D. alatus *metre-gauge sleepers with* Solignum *and* Liquid Fuel, *and a few sleepers with* Liquid Fuel *only.*

These sleepers were treated under the directions of the writer, by Babu Gyan Singh, at Pyinmana, on the Burma Railways. The solution used consisted of two parts *Liquid Fuel* and one part *Solignum*, and the treatment aimed at introducing 5 lbs. of the solution into each metre-gauge sleeper. The actual number of sleepers handed over to the Railways was 500 *Dipterocarpus alatus* and 470 *D. tuberculatus* metre-gauge sleepers treated with mixed *Liquid Fuel* and *Solignum*, and 30 of the latter species impregnated with *Liquid Fuel* oil only.

To ascertain the period of immersion necessary to make the sleepers take up 5 lbs. of oil each, batches of sleepers were weighed before and after immersion, with the following results :—

TABLE XXI.

Species.	Average absorption, per sleeper, of 22 sleepers.	Temperature of the solution.	Period of immersion.
	lbs.		
Dipterocarpus alatus, metre-gauge sleepers.	2·25	75°C. dropping to 63°C. .	2 hours heating and 4 hours cooling = 6 hours.
Ditto . .	4·1	75°C. and then allowed to cool down.	2 hours heating and 7 hours cooling = 9 hours.
Ditto . .	3·9	Ditto . .	2 hours heating and 7½ hours cooling = 9½ hours.
Ditto . .	5·4	Ditto . .	2 hours heating and 11 hours cooling = 13 hours.
Ditto . .	5·3	Ditto . .	Ditto.
Ditto . .	4·3	80°C. and then allowed to cool down.	2 hours heating and 8 hours cooling = 10 hours.
Ditto . . .	4·6	Ditto . .	Ditto
Ditto . .	3·9	Ditto . .	Ditto

Average absorption of all but the 1st lot, which was a trial run, *i.e.*, of 154 sleepers in all = 4·6 lbs. per metre-gauge sleeper.

The rest of the sleepers of this species were treated with a 12 hours immersion period. The *Dipterocarpus tuberculatus* sleepers were dealt with in a similar manner with the following results :—

TABLE XXII.

Species.	Average absorption per sleeper, of 22 sleepers.	Temperature of the solution.	Period of immersion.
	lbs.		
Dipterocarpus tuberculatus, metre-gauge sleepers.	3·45	80°C.	2 hours heating and 9 hours cooling = 11 hours.
Ditto .	4·1	85°C.	Ditto
Ditto .	4·5	84°C.	2 hours heating and 9½ hours cooling = 11½ hours.
Ditto .	4·7	89°C.	2 hours heating and 10 hours cooling = 12 hours.
Ditto .	4·4	85°C.	2 hours heating and 12 hours cooling = 14 hours.
Ditto .	4·4	Ditto	2 hours heating and 13 hours cooling = 15 hours.
Ditto .	6·25	Ditto	2 hours heating and 14 hours cooling = 16 hours.
Ditto .	6·1	Ditto	Ditto
Ditto .	5·0	Ditto	Ditto
Ditto .	4·6	Ditto	Ditto
Ditto .	4·25	Ditto	Ditto
Ditto .	5·4	Ditto	Ditto

Average absorption of 132 sleepers treated under a 16-hours' immersion period = 5·29 lbs. per metre-gauge sleeper.

The results of these experiments show that *Dipterocarpus alatus* is easier to treat than *D. tuberculatus,* as 12 hours in the case of the former and 16 hours in the case of the latter, are required to make a metre-gauge sleeper take up about 5 lbs. of oil. On the other hand, the results show variation in absorption by the same species, when treated under precisely the same conditions. This is attributed to the varying percentages of sap-wood and possibly moisture in each batch of sleepers. Another point brought out by these experiments is that on account of the long immersion period necessary to make the sleepers take up even a small quantity of oil, by the Open Tank process, it would probably be cheaper and certainly more expeditious, to treat them under pressure.

(*c*) *Treatment of* Terminalia tomentosa *broad gauge sleepers, with* Solignum *and* Liquid Fuel *oil.*

The *Terminalia tomentosa* broad gauge sleepers were treated in a mixture consisting of 33 per cent. of *Solignum* and 67 per cent. of *Liquid Fuel* oil, the object aimed at being to introduce 9 to 10 lbs. of the solution into each broad gauge sleeper. The work was started by the writer who, after fixing the immersion period necessary to make the sleepers take up the required quantity of oil, entrusted the work to his assistant, Babu Gyan Singh.

The sleepers were prepared from trees felled during the working season of 1913, in the Betul forests, and were treated in November 1914, having therefore had 16 to 18 months in which to season. An attempt was made to treat these sleepers in February 1914, but as they were at that time insufficiently seasoned, the work was postponed until the following November.

To ascertain the period of immersion necessary in order to make the sleepers take up 9 to 10 lbs. of oil, 25 per cent. of the sleepers were weighed before and after treatment, with the following results :—

TABLE XXIII.

Species.	Average absorption, per sleeper, of 19.	Temperature of the solution.	Period of immersion.
	lbs.		
Terminalia tomentosa, broad gauge sleepers.	10·1	89°C. dropping to 49°C.	3 hours heating and 21 hours cooling=24 hours.
	9·4	90°C. „ 51°C.	Ditto
	8·95	90°C. „ 50°C.	Ditto
	10·3	90°C. „ 53°C.	Ditto
	9·25	90°C. „ 51°C.	Ditto
	10·6	90°C. „ 45°C.	Ditto

Average absorption per broad gauge sleeper of 114 sleepers=9·77 lbs.

The most noticeable point in the above figures is the marked regularity in absorption, which is attributed to the sleepers being well-seasoned and containing little sap-wood. The immersion period of 24 hours is a long one, but when the close, hard nature, of the timber is taken into consideration, the quantity of oil absorbed is surprisingly high. The sleepers, after treatment, were handed over to the Great Indian Peninsula Railway authorities and laid in the line.

(*iii*) COST OF TREATING SLEEPERS WITH *Solignum* AND *Liquid Fuel* OIL, MIXED IN VARYING QUANTITIES.

When considering the financial aspect resulting from treating sleepers with *Solignum* and *Liquid Fuel* oil, it must be borne in mind that *Solignum*, though, as before stated, a very high class *coal-tar creosote* preparation, is also very expensive, while *Liquid Fuel* in comparision, is cheap. Results alone can prove whether the use of so costly an oil as *Solignum* is justified.

(*a*) *Cost of treating 350* Pinus longifolia *and 100* P. excelsa *broad gauge sleepers.*

The mixture in which the sleepers were treated consisted of 40 per cent. *Solignum* and 60 per cent. *Liquid Fuel* oil.

	Rs.	A.	P.
Cost of felling, converting and landing 350 broad gauge sleepers at Jagadhri	350	0	0
Cost of *Liquid Fuel* oil at 5 annas per gallon, including freight to Jagadhri, each sleeper absorbing 9 lbs. of oil, of which 3-5th was *Liquid Fuel* oil, to treat 350 broad gauge sleepers	59	1	0
Cost of *Solignum* at Rs. 3 per gallon, each sleeper absorbing 2-5th of 9 lbs. or 3·6 lbs.	378	7	0
Cost of coolie labour, fuel and miscellaneous expenses .	63	0	0
5 per cent. cost of plant	21	0	0
2 per cent. due to evaporation and leakage of oil . .	38	0	0
Total cost of treating 350 broad gauge *Pine* sleepers .	909	8	0
Average cost of treating a broad gauge *Pine* sleeper .	2	9	10

The *Solignum* oil was actually supplied from England, free of charge, by the India Office. In the above calculations its value is placed at Rs. 3-0-0 per gallon, at which price it can be purchased in India. The cost of exploiting the sleepers and landing them on rail at Jagadhri came to Re. 1-0-0 per sleeper, therefore the cost of treatment came to Re. 1-9-10 per broad gauge *Pine* sleeper. Royalty charges are not included in the above calculations ; broad gauge *Pinus longifolia* untreated sleepers can be purchased at Jagadhri in large numbers for Rs. 3-0-0, to which must be added 4 annas royalty on treatment and Re. 1-9-10 the cost

of treatment. It follows, that were such an undertaking contemplated on commercial lines, the Railways would have to pay Rs. 4-14-0 per broad gauge *Pinus longifolia* sleeper treated with 9 lbs. of *Solignum* and *Liquid Fuel* oil, mixed in the proportion of 4 to 6.

(*b*) *Cost of treating 470* Dipterocarpus tuberculatus *and 500* D. alatus *metre-gauge sleepers, with a mixture of 33 per cent. of* Solignum *and 66 per cent. of* Liquid Fuel *oil.*

	Rs.	A.	P.
Cost of felling, conversion and extraction of 970 metre-gauge sleepers to Pyinmana	1,212	8	0
Cost of 33 per cent. of 4·7 lbs. of *Solignum* required per sleeper, for 970 metre-gauge sleepers, costing Rs. 3 per gallon	454	11	0
Cost of 66 per cent. of 4·7 lbs. of *Liquid Fuel* oil required per sleeper, for 970 metre-gauge sleepers, costing 4 annas per gallon in Rangoon	76	0	0
Coolie wages, fuel, and miscellaneous expenses incurred in treatment	296	14	0
5 per cent. on cost of plant	51	0	0
2 per cent. loss by evaporation and leakage	9	0	0
Total cost of treating 970 metre-gauge *Dipterocarp* sleepers	2,100	1	0

Average cost of treating a metre-gauge *Dipterocarp* sleeper = Rs. 2 2 8

The cost of felling, conversion and extraction per metre-gauge sleeper comes to slightly under Re. 1-4-0; the cost of treatment was therefore Re. 0-14-8, to which would have to be added at least 7 annas 4 pies for royalty on the timber and for treatment, making a total of Rs. 2-10-0 per metre-gauge sleeper.

(*c*) *Cost of treating 460* Terminalia tomentosa *broad gauge sleepers with a mixture of 33 per cent. of* Solignum *and 66 per cent. of* Liquid Fuel *oil.*

	Rs.	A.	P.
Cost of felling, conversion and extraction of 460 broad gauge sleepers	1,561	2	0
Cost of ⅓rd of 10 lbs. of *Solignum* per sleeper, for 460 broad gauge sleepers, costing Rs. 3-0-0 per gallon .	460	0	0
Cost of ⅔rd of 10 lbs. of *Liquid Fuel* oil, required per sleeper, for 460 broad gauge sleepers, 5 annas per gallon, including freight	95	11	0
Coolie labour, fuel and miscellaneous charges . .	116	0	0
5 per cent. on cost of plant	17	0	0
2 per cent. due to leakage and evaporation of oil . .	11	2	0
Total cost of treating 460 broad gauge *Terminalia tomentosa* sleepers	2,260	15	0

Average cost of treatment per broad gauge *Terminalia tomentosa* sleeper = Rs. 4-14-8.

(*iv*) NOTES ON THE BEHAVIOUR OF SLEEPERS TREATED WITH *Solignum* AND *Liquid Fuel* OIL, AFTER HAVING BEEN LAID IN THE LINE.

The *Dipterocarp* sleepers, treated with *Solignum* and *Liquid Fuel*, were laid down in June 1914, the *Pine* and *Deodar* sleepers in November of the same year, and the *Terminalia* sleepers in June 1915, so that not until a further period of 2 or 3 years has lapsed can anything approaching reliable results be expected. It is, however, necessary to place on record where and under what conditions, the sleepers have been laid.

TABLE XXIV.

Record of sleepers treated with Solignum *and* Liquid Fuel *oil and laid for experimental purposes in different sections of the line.*

Species.	Number of sleepers laid down.	Locality where laid down.	Date of laying in line.	Date of last inspection.	Inspection notes.	Remarks.
Pinus longifolia, or 'Chir.'	83 broad gauge sleepers.	Between Sohanwala and Amruka, mile 149/16-17, Ferozepur District, North-Western Railway.	November 1914	1st March 1917	Sixty-six slightly cracked and three attacked by white-ants, rest in good order. (Inspected by Mr. Sham Lal, North-Western Railway.)	Laid with bearing-plates Branded P. L. / S.L.F.
Ditto	Do.	Between Fazilka and Ladhuka, mile 123/15-17, Ferozepur District, North-Western Railway.	Do.	Do.	Sixty-four slightly cracked, and one attacked by white-ants, rest in good order. (Inspected by Mr. Sham Lal, North-Western Railway.)	Do.
Ditto	Do.	Between Gurubarsahai and Jhok Tahl Singh, mile 95/6-7, Ferozepur District, North-Western Railway.	Do.	3rd March 1917	Sixty-eight slightly cracked and three attacked by white-ants, rest in good order. (Inspected by Mr. Sham Lal, North-Western Railway.)	Do.
Pinus excelsa, or 'Kail.'	33 broad gauge sleepers.	Between Sohanwala and Amruka, mile 149/16-17, Ferozepur District, North-Western Railway.	Do.	1st March 1917	Twenty-four slightly cracked, rest in good order. (Inspected by Mr. Sham Lal, North-Western Railway.)	Laid with bearing plates Branded P. E. / S. L. F.
Ditto	Do.	Between Fazilka and Ladhuka, mile 123/15-17, Ferozepur District, North-Western Railway.	Do.	Do.	Twenty-five slightly cracked, and one attacked by white-ants, rest in good order. (Inspected by Mr. Sham Lal, North-Western Railway.)	Do.
Ditto	34 broad gauge sleepers.	Between Gurubarsahai and Jhok Tahl Singh, mile 95/6-7, Ferozepur District, North-Western Railway.	Do.	3rd March 1917	Twenty-three slightly cracked, and one attacked by white-ants, rest in good order. (Inspected by Mr. Sham Lal, North-Western Railway.)	Do.

Dipterocarpus tuberculatus, or 'In.'	30 metre-gauge sleepers, treated with Liquid Fuel only.	Pyinmana, mile 225/14¾ 15¼, Burma Railways.	22nd June 1914	3rd June 1916 .	Very good, not rotting, all holding well. (Inspected by A. Rodger, Esq., Forest Research Officer, Burma, and Assistant Engineer, Yamethin.)	Marked $\frac{\text{D. T.}}{\text{L. F.}}$
Ditto .	470 metre-gauge sleepers treated with *Solignum* and *Liquid Fuel.*	Pyinmana, mile 225/19½ to 226/4¼, Burma Railways.	Do. .	Do. .	All good, a few slightly cracked, not rotting. (Inspected by A. Rodger, Esq., Forest Research Officer, Burma, and Assistant Engineer, Yamethin.)	Marked $\frac{\text{D. T.}}{\text{S. L. F.}}$
Dipterocarpus alatus or 'Kanyin.'	500 metre-gauge sleepers.	Pyinmana, mile 225/15¼ to 225/19¼, Burma Railways.	Do. .	Do. .	All good, a few cracked, and one or two beginning to rot. (Inspected by A. Rodger, Esq., Forest Research Officer, Burma, and Assistant Engineer, Yamethin.)	Marked $\frac{\text{D. A.}}{\text{S. L. F.}}$
Terminalia tomentosa or 'Sain.'	460 broad gauge sleepers.	Near entrance to Parassia Station, mile 598/78 to 596/97, Itarsi-Nagpur Railway, Great Indian Peninsula.	9th June 1915 .	6th July 1916 .	Up to the present these sleepers are very good. I can see no signs of decay. (Inspected by the Chief Engineer, Great Indian Peninsula Railway).	Branded $\frac{\text{T. T.}}{\text{S. L. F.}}$
Cedrus Deodara or 'Deodar.'	16 broad gauge sleepers.	Between Sohanwala and Amruka, mile 149/16-17, Ferozepur District, North-Western Railway.	November 1914	1st March 1917.	Nine slightly cracked, rest in good order. (Inspected by Mr. Sham Lal, North-Western Railway.)	Branded $\frac{\text{C. D.}}{\text{S. L. F.}}$
Ditto .	18 broad gauge sleepers.	Between Gurubarsahai and Jhok Tahl Singh, mile 95/6-7, Ferozepur District, North-Western Railway.	Do. .	3rd March 1917 .	Nine slightly cracked, rest in good order. (Inspected by Mr. Sham Lal, North-Western Railway.)	Do.
Ditto .	16 broad gauge sleepers.	Between Fazilka and Ladhuka, mile 123/15-17, Ferozepur District, North-Western Railway.	Do. .	1st March 1917 .	Four slightly cracked, rest in good order. (Inspected by Mr. Sham Lal, North-Western Railway.)	Do.

(v) General conclusions based on the results of sleepers treated with *Solignum* and *Liquid Fuel* oil and laid in the line.

The sleepers which have been in the line from 2 to 3 years are so far doing quite well. The only data available at present, from which it is possible to draw definite conclusions, is the figure of cost of treating sleepers with mixed oils. The cost of treating *Pine* broad gauge sleepers comes to Re. 1-9-10, that of *Dipterocarp* metre-gauge sleepers to Re. 0-14-8 and that of *Terminalia tomentosa* broad gauge sleepers to Re. 1-8-4. The amount of oil introduced was not up to that usually used in treating sleepers; nevertheless, the cost is high and, though possibly not prohibitive, it is questionable whether the results obtained will justify the use of so expensive an oil as *Solignum.* Possibly a far cheaper grade of *coal-tar creosote,* such as *Green oil,* would answer the purpose equally well, which would at the same time reduce the cost of treatment to somewhere about Re. 1-0-0 per broad gauge sleeper, while the amount of oil admissible would be greater than that actually used in the above experiments.

10. General Conclusions arrived at from the above Experiments.

The merits and defects of the various processes above described have been discussed in detail under their separate headings, so that it is here only proposed to briefly review the results from a general point of view.

The experiments demonstrate in a striking manner the possibilities and limitations of the Open Tank Process of treatment. In its favour, it may be said that it is a simple process when compared with those involving pressure; that the period of immersion necessary in the case of soft-woods is not excessive, while that necessary for hard-woods limits the possible number of sleepers to be treated, unless the plant units be multiplied beyond working limits. Thus, any schemes involving the treatment of more than 50,000 *Pine* sleepers or more than 25,000 hard-wood sleepers per annum should not be based on the Open Tank Treatment, as greater quantities of sleepers could more effectively be treated in pressure cylinders.

As regards absorption of an antiseptic solution by timber when treated in Open Tanks, unless the timber be exceptionally easy to treat or the period of immersion be unduly long, the sleepers rarely take up on an average more than 5 to 6 lbs. per cubic foot. It is true that sappy 'Chir' sleepers have been known to take up as much as 15 lbs. per cubic

foot, but this is not the rule. A heart-wood 'Chir' sleeper will take up 5 lbs. to 6 lbs. per cubic foot within 18 to 24 hours, while a combined sap and heart-wood 'Chir' will take up the same quantity in 6 to 10 hours, according to its dryness. Both *Dipterocarps* and *Terminalia tomentosa* will take up 3 to 4 lbs. per cubic foot in 24 hours and, if immersed for a longer period, take up very little extra oil. It may, therefore, be said that in Open Tanks, when working with sleeper sizes, the outside working limit is 6 lbs. per cubic foot under favourable conditions.

The choice of antiseptics in these experiments was governed by their efficiency combined with cheapness, and though the results did not, in some cases, justify their selection, the general lines adopted are thought to have been correct. To form a correct idea as the cost of treatment it is necessary to compare the figures obtained, with the cost of treatment generally adopted in Europe and America, when using a full charge of *coal-tar creosote* which, in India, would amount to Rs. 2-4-0 per broad gauge sleeper.

In comparison with this figure, all our results compare most favourably ; nevertheless, in some cases, the actual cost of treatment was excessive, as in the case of *Terminalia tomentosa* broad gauge sleepers, treated with *Solignum* and *Liquid Fuel* oil, which came to Re. 1-8-4 and of *Pines*, treated with the same mixture of oils, which came to Re. 1-9-10 per sleeper.

From experience gained in carrying out these experiments, it has been possible to form more correct ideas as to the application of the principles of mixing oils or oils and salts together, in order to reduce cost without, as far as one can see, impairing the toxic value of the solutions.

The first set of experiments deal with *Powellized* timber, a patented process which cannot be altered and therefore the cost of treatment is dependent on the market value of the ingredients used, and though the cost of treatment is relatively high, in favourable localities it cannot be considered as prohibitive.

The second set of experiments were carried out with *Avenarius Carbolineum*, an expensive oil, which introduced in any quantity renders the cost of treatment prohibitive. This oil, when used alone cannot at present be considered for treating sleepers in India as it is too expensive.

The third group of experiments were carried out with *Chloride of Zinc* and either *Green oil* or *Avenarius Carbolineum*. Here we have a relatively cheap process of treatment, when using the salt and *Green oil*, for it only costs Re. 1-1-4 to treat a broad gauge pine sleeper with

15 lbs. of the salt and 4 lbs. of the oil, and 6 annas 5 pies for a *Dipterocarp* metre-gauge sleeper with 9 lbs. of the salt solution and 1 lb. of oil. Without doubt the cost of treatment could be still further reduced, as 6 annas 10 pies per gallon is above the usual rate for *Green oil* in Europe. Or again, a good grade of *Coal-tar* creosote at 4 annas 6 pies per gallon could be substituted, which would further reduce cost of treatment, probably without seriously affecting the efficiency of the process.

The 4th and last group of experiments were carried out with a mixture of *Solignum* and *Petroleum* oils. The oils used were *Solignum* and *Liquid Fuel*; here again costs run higher than they should have done, due to the high price of *Solignum.* However, by applying the principle of mixing *Coal-tar* products with *Petroleum* oils and using, for instance, *Green oil* or a good grade of *creosote,* as used for treating timber in Europe, the results obtained are very different. The mixture instead of costing about Re. 1-10-0 per gallon, as was the case with *Solignum* and *Liquid Fuel,* is reduced to 9 or 10 annas per gallon. Putting the maximum cost of treatment admissible at Re. 1-4-0, this will permit of somewhere in the neighbourhood of 18 lbs. of the solution being introduced per broad gauge sleeper, a larger amount than was used in any of the above experiments.

The durability tests have hardly been carried far enough to justify definite statements being made, while the results have been discussed in detail elsewhere, so need not be dealt with again; sufficient is it to say that to date none of the sleepers have shown any serious signs of failure.

PART IV.

MISCELLANEOUS FIELD EXPERIMENTS CARRIED OUT WITH SLEEPERS TREATED IN OPEN TANKS.

Several experiments in connection with the antiseptic treatment of timber, other than those carried out according to the scheme drawn up at the Forest Research Institute in 1910 and described in Part III of this note, have been made of recent years in India. These experiments were either started by Indian Railway Engineers, or at the instigation of firms interested in any special process or were in the nature of supplementary experiments to those enumerated in Part III, and carried out by the Forest Department. For convenience sake, these experiments are arranged according to the antiseptic employed, irrespective of the agency of treatment.

Photo.-Mechl. Dept., Thomason College, Roorkee. Photo by T. B. Chitrakar.

Full cell Open Tank process—*Pinus longifolia* sap and heart-wood ½ section of a sleeper, treated for 8 hours in Creosote and Earth oil, raised to a temperature of 73°C. dropping to 65°C. Absorption 10·3 lbs. per c. ft.

[*To face page* 71.

1. Treatment of sleepers with mixed oils.

(i) SPECIAL EXPERIMENTS CARRIED OUT WITH *Pinus longifolia* SLEEPERS TREATED IN OPEN TANKS.

The interest taken by the Railway Authorities in the experiments described in Part III, combined with their urgent need for sleepers, enabled Mr. Hart, the Inspector-General of Forests, to arrange a contract by which the Forest Department was to supply the State Railways with a million treated *Pinus longifolia* broad gauge sleepers within four years. The possibility of carrying out the contract was facilitated by the fact that the United Provinces Forest Department was anxious to place large quantities of this timber on the market from the newly formed Kumaon Circle. In connection with this work, three installations have been erected at Kathgodam and Tanakpur on the Rohilkund and Kumaon Railway, and at Hardwar on the Oudh and Rohilkhand Railway.*

To ascertain the period of immersion necessary, in order to make the sleepers take up 15 lbs. of oil each, experiments were carried out as soon as the first unit of the new plant was in working order. The oil used was a mixture of equal parts, by weight, of *Green oil*, which is a good grade of creosote, with high boiling fractions and *Liquid Fuel* with a *Petroleum* base. Soon after starting the experiments it was ascertained that to obtain more uniform absorption of the oil, it was necessary to divide the sleepers into two groups, according to whether they contained sap-wood in addition to heart-wood or not. Little difficulty has been experienced in doing so, and this procedure has been in force up to date.

* NOTE.—The works have recently been closed, owing to creosote not being available from Europe.

The following are some of the results obtained by treating *Pinus longifolia* broad gauge sleepers in the United Provinces treating tanks :—

TABLE XXV.

Experiments carried out with Pinus longifolia or *'Chir' broad gauge sleepers in the United Provinces Open Tank installations, at Kathgodam, Tanakpur and Hardwar, to ascertain the necessary period of immersion in order to make the sleepers take up 15 lbs. of oil each.*

Serial No. of experiment.	No. of broad gauge sleepers on which the average is based.	Total period of immersion, in hours.	Temperature of the oil.	Average amount of oil absorbed per sleeper, in lbs.	REMARKS.
	(i) *Heart-wood* Pinus longifolia *broad gauge sleepers.*				
1	20	24	Heated to 81°C. for 4 hours and allowed to cool to 43°C.	16·4	Seasoned sleepers. Experiments carried out by Forest Economist at Kathgodam in April 1914.
2	20	24	Heated to 80°C. for 4 hours, 20 hours cooling to 42°C.	15·4	
3	15	24	Heated to 86°C. for 4 hours, dropping to 41°C.	16·1	
4	10	17	Heating to 80°C., dropping to 45°C.	10·0	
5	20	24	Heating to 80°C., dropping to 40°C.	8·8	Seasoned sleepers, which were launched for floating purposes and taken out of the stream 18 days before treatment. Treated by the Forest Economist at Kathgodam in April 1914.
6	7	15	Heating to 80°C. for 2½ hours.	12·3	Well-seasoned sleepers. Experiments carried out by J. Donald, Esq., and the Senior Provincial Service Class in April 1914 at Kathgodam.
7	19	16	Heating to 83°C., dropping to 52°C.	13·2	Thoroughly seasoned heart-wood sleepers, containing very little sap. Experiments carried out by Forest Economist at Tanakpur in January 1915.
8	19	19	Heating to 93°C., dropping to 60°C.	14·4	
9	18	20	Heating to 93°C., dropping to 50°C.	16·6	
10	18	26	Heating to 85°C. . .	13·1	Seasoned sleepers containing no sap ; the sleepers, however, though seasoned, were damp due to the monsoon rains. Treated by C. E. C. Cox, Esq., Assistant, Forest Economist at Hardwar, in August 1915.
TOTAL .	166	209	....	136·3	
AVERAGE	1	20·9	Heated to 84°C., dropping to 47°C.	13·6	

TABLE XXV—*contd.*

Serial No. of experiment.	No. of broad gauge sleepers on which the average is based.	Total period of immersion in hours.	Temperature of the oil.	Average amount of oil absorbed per sleeper, in lbs.	REMARKS.
			(ii) *Sap and heart-wood* Pinus longifolia *broad gauge sleepers.*		
1	10	17	Heated to 80°C., dropping to 45°C.	17·8	Seasoned sleepers, containing a large proportion of sap-wood. Treated by Forest Economist at Kathgodam in April 1914.
2	20	9	Heated to 86°C., dropping to 74°C.	7·1	Ditto
3	20	6	Heated to 50°C. . .	7·5	Ditto
4	20	5	Heated to 90°C. for four hours and allowed to cool to 82°C.	14·5	Very thoroughly seasoned sleepers containing at least ⅓rd sap-wood. Treated by Forest Economist at Tanakpur in January 1915.
5	20	5	Heated to 71°C., dropping to 54°C.	17·1	Ditto
6	16	8	Heated to 80°C., dropping to 65°C.	4·25	Sap-wood sleepers, only having been out of the floating stream 10 days and therefore containing an excess of moisture. Treated by Forest Economist at Tanakpur in January 1915.
7	20	8	Heated to 73°C., dropping to 63°C.	19·1	Very thoroughly seasoned sleepers, 18 months out of floating stream. The sleepers contained on an average one-third of sap. Treated by Forest Economist in November 1915.
TOTAL .	126	58	....	87·35	
Average .	1	8·3	Heated to 76°C., dropping to 64°C.	12·5	

NOTE.—Omitting No. 6 which contained green sleepers, the average works out to 13·85 lbs. per sleeper.

From the above experiments it was ascertained that—

(*i*) the maximum period of immersion necessary for heart-wood *Pinus longifolia* broad gauge sleepers, in order to make them take 15 lbs. of oil each, is 24 hours, with the temperature of the oil raised to 80°C., maintained at that temperature for 4 hours and then allowed to cool down.

(*ii*) The maximum period of immersion necessary for sleepers containing $\frac{1}{3}$rd of sap-wood or more, in order to make them take up 15 lbs. of oil each, is 12 hours, with temperatures as above.

(*iii*) When dealing with sleepers which have been 18 months or more out of the floating stream, 18 hours' immersion for

heart-wood and 6 hours' immersion for sap and heart-wood sleepers is sufficient to make them take up 15 lbs. each.

(*iv*) It is not only useless but wrong to treat sleepers recently taken out of the floating stream, even if they are thoroughly seasoned, before being thrown into the stream for floating purposes. The minimum period for seasoning, after the sleepers have been removed from the floating stream, is 4 months in the cold weather and 3 months in the hot weather.

(*v*) The main factors regulating the rate of absorption of oil by any one species of timber are : (*i*) the percentage of moisture in the timber, at the time of treatment, (*ii*) the difference in the maximum and minimum temperature of the oil during treatment ; the greater the difference, the greater the rate of absorption and quantity of oil taken up, (*iii*) the percentage of sap to heart-wood, and (*iv*) structure.

(*ii*) TREATMENT OF ASSAM SPECIES OF TIMBER IN OPEN TANKS.

In 1912, when the writer was on tour in Assam, the question of supplying the Assam-Bengal Railway with treated sleepers came under discussion, and proposals were made to carry out experiments with a species of timber known as *Cynometra polyandra* ; later, the scope of scheme was further extended by Mr. Perreé, the then Conservator of Forests of the Eastern Circle, by the addition of other species of timber. Under his directions, an experimental Open Tank plant was erected at Jaipur by Mr. Cooper, the Divisional Forest Officer of the Lakhimpur Division, and the sleepers for the experiment prepared and seasoned. In February 1915, Messrs. Perreé and Cooper, in company with the writer, proceeded to Jaipur to carry out these experiments.

The species of timber selected for testing were (*i*) *Artocarpus Chaplasha* 'Cham,' (*ii*) *Dipterocarpus pilosus* 'Hollong,' (*iii*) *Altingia excelsa* 'Jutuli,' (*iv*) *Cynometra polyandra* 'Ping', (*v*) *Terminalia myriocarpa* 'Hollock' and (*vi*) *Terminalia belerica* 'Bhumra.'

The timber was allowed to season in the log and was then cut into metre-gauge sleepers and allowed further to season under cover for from 8 months to 2 years. The timber was, therefore, thoroughly dry, while the absence of cracks was very noticeable, an important point demonstrating the great value of slow and thorough seasoning.

The solution used to treat the sleepers was *Green oil* and crude *Earth* or *Petroleum* oil, mixed in equal quantities by weight.

The results of the experiments are tabulated below :—

TABLE XXVI.

Experiments carried out at Jaipur, Lakhimpur Division, Assam, to ascertain the penetration of oil into 8 Assam species of timber, when treated in Open Tanks.

Serial No. of experiments.	Species.	No. of metre-gauge sleepers, on which the average is based.	Total period of immersion, in hours.	Temperature of the oil.	Average amount of oil absorbed per sleeper, in lbs.	REMARKS.
1	*Artocarpus Chaplasha* 'Cham.'	2	24	Heated from 85°C. to 93°C., dropping to 35°C.	0·5	Practically no penetration at all.
2	*Dipterocarpus pilosus* 'Hollong.'	10	24	Ditto .	9·7	The absorption was on the whole uniform, the extremes being 6·5 lbs. and 14 lbs. per sleeper.
3	*Altingia excelsa* 'Jutuli'	8	24	Ditto .	4·25	Absorption irregular, varying from 1 lb. to 7·5 lbs. per sleeper.
4	*Cynometra polyandra* 'Ping'.	8	24	Ditto .	9·2	Absorption irregular, varying from 3·5 lbs. to 18 lbs. per sleeper.
5	*Terminalia myriocarpa* 'Hollock.'	2	24	Ditto .	2·75	Absorption indifferent.
6	*Terminalia belerica* 'Bhumra.'	2	24	Ditto .	25	Absorption excessive, a soft timber, hardly suitable for sleepers.

The above experiments, though only carried out on a small scale, indicate that it is possible to treat *Dipterocarpus pilosus* 'Hollong,' *Terminalia belerica* 'Bhumra,' and *Cynometra polyandra* or 'Ping' by the *Open Tank* process. Of these timbers, *Terminalia belerica* is mechanically hardly strong enough to be used for sleepers; *Dipterocarpus pilosus* is a good straight-grained timber which, owing to the large pores in the timber readily absorbs any solution in which it is placed. *Cynometra polyandra* is a hard timber, and it therefore came as somewhat of a surprise that it took up the oil so readily. *Terminalia myriocarpa* and *Artocarpus Chaplasha* do not lend themselves to treatment in Open Tanks; in fact, attempts to treat the former timber under pressure were equally unsuccessful. This is to be regretted as both are sound good timbers, though not sufficiently durable for sleeper work, unless previously treated with a suitable antiseptic. The remaining species, namely, *Altingia excelsa* took up relatively small quantities of oil, though it would probably lend itself to pressure treatment.

These sleepers, together with a number of sleepers treated under pressure, the record of which work is given in the next chapter, were laid down in the Assam-Bengal Railway in October and November 1915, and are to be kept under observation. As they have not been in the line a year, their condition is not recorded.

(*iii*) TREATMENT OF *Dipterocarpus turbinatus*, 'GURJAN' BROAD GAUGE SLEEPERS OBTAINED FROM THE ANDAMANS, IN OPEN TANKS.

A scheme having been put forward to supply the State Railways with treated *Dipterocarp* sleepers from the Andamans, a sample lot of seasoned broad gauge Gurjan sleepers were submitted, for testing their power of absorption in Open Tanks. Twenty sleepers were immersed for 24 hours in a mixture of *Green oil* and *Liquid Fuel* oil, heated for 5 hours to 72°C. and allowed to cool down in the bath for a further period of 19 hours. This resulted in the sleepers taking up an average of 15·1 lbs. each. One or two of the sleepers took up an excessive amount of oil, amounting to 28 lbs., while a few only took up 4 to 6 lbs; on the whole, however, the absorption was fairly regular. It is evident that this species of timber is not difficult to treat even in Open Tanks, though probably quicker and better results would be obtained by treating it under pressure.

2. Sleepers treated with Crésol-Calcium.

In December 1910, the North-Western Railway laid down, as an experiment, 499 Swedish pine sleepers treated with *Crésol-Calcium.*

These sleepers were supplied by the *Crésol-Calcium* Impregnating Aktiebolag Company and laid by the North-Western Railway from mile 315/12 to 315/18, between Sangi and Pans Akil stations on the Sukkur Section.

The latest report submitted by the Executive Engineer, Sukkur, dated 24th October 1915, on the condition of these sleepers, states that one has been rejected, due to attack by white-ants, and puts 120 into A class, 250 into B class and 123 into C class. The reason for classifying 373 sleepers in classes B and C is due to the ends having cracked and split and is not due to white-ant attacks. The cut under the bearing plates is reported as not severe, while the spikes are holding well. The report states that some of the C class sleepers are now hardly serviceable for the main line where trains run at a high speed.

The point of interest about this experiment is that the sleepers, with the exception of one, have not been touched by white-ants, in a section of the line which is notorious for these pests. These sleepers are laid in continuation of the *Powellized sleepers*, the records of which are given in the previous chapter, which have also so far withstood the ravages of white-ants. It may be stated here that untreated Jarrah, and also in some cases untreated Deodar, have suffered heavily from white-ant attacks in this section of the North-Western Railway.

3. Sleepers treated with Jodelite and laid in the Burma Railways.

In Chapter III are recorded the results of experiments carried out in Burma with a few *Powellized* species; at the same time as these sleepers were laid down, a similar set of sleepers treated with *Jodelite* were placed alongside them. Exactly how the sleepers were treated with *Jodelite* is not recorded, but it is thought that the solution was applied with a brush, giving the timber one or more coats of the oil. These experiments are of interest having been in progress longer than any others in British India. The results of an inspection carried out on the 3rd June 1916 by A. Rodger, Esq., Forest Research Officer, Burma, and the Assistant Engineer, Yamethin, are as follows :—

TABLE XXVII.

Record of sleepers treated with Jodelite.

No.	Species.	Sleepers treated with *Jodelite.*			Untreated sleepers.		
		No. laid down.	Date of laying in line.	Condition.	No. laid down.	Date of laying in line.	Condition.
1	*Dipterocarpus tuberculatus,* or 'In.'	10	15th April 1908.	The 5 left in 1915 are still in the line, one must be removed, as it is badly cracked and rails have eaten in.	10	15th April 1908.	The two remaining sleepers seen in 1915 have been removed, rotten and cracked.
2	*Dipterocarpus alatus* or 'Kanyin.'	10	Do.	All removed in 1911-12. (Experiment closed.)	10	Do.	All removed in 1913.
3	*Homalium tomentosum* or 'Myoukchow.'	10	Do.	Only two left, spikes do not bite at all well, slightly cracked, otherwise good, no sign of rot.	10	15th April 1907.	All removed by 1911.
4	*Schleichera trijuga* or 'Gya.'	10	Do.	All removed by 1912.	10	Do.	All removed by 1913.
5	*Terminalia belerica* or 'Thitsein.'	10	Do.	All removed by 1911.	10	Do.	All removed by 1909.
6	*Terminalia tomentosa* or 'Taukkyam.'	10	Do.	5 are left, one must come out, all rather cracked, but good for another year. Spikes holding. Rails have not cut into the timber badly.	10	Do.	All removed by 1913.
7	*Lagerstrœmia tomentosa* or 'Lezo.'	10	Do.	Only one left, but it is badly split and spikes not holding. May last another year.	10	April 1908.	All removed in 1912.

The results of the above experiments show that 50 per cent. of the *Dipterocarpus tuberculatus* and *Terminalia tomentosa* sleepers are still in the line after more than eight years, while the first-named species has only a life of 4 to 5 years in an untreated state. Five out of ten of the *Terminalia tomentosa* sleepers are still present, as against all the untreated sleepers removed in five years. The other species of timber have given poor results. It was stated above that the method of treatment was probably by applying one or more coatings of the solution which, generally speaking, is not sufficient to protect sleeper woods from decay.

PART V.

RECORDS OF EXPERIMENTS CARRIED OUT WITH SLEEPERS TREATED IN PRESSURE PLANTS WITH INDIAN AND OTHER VARIETIES OF TIMBER.

1. Records of former Experiments carried out in Pressure plants, previous to 1910.

In *Indian Forest Records*, Volume III, Part II, on pages 17-23, is given a brief record of the experiments carried out in the past on timber treated under pressure in India while, in a letter from the Secretary to the Railway Board to the Inspector-General of Forests to the Government of India, a résumé is also given of the work carried out in past years. As this letter is an open one and clearly and briefly sums up the position of affairs as it stood in India in 1910, it is given here in full.

" In reply to your letter No. 1406-394—1, dated 28th October 1909, I am directed to say that papers available in this office contain no records of any systematic experiments carried out on Indian Railways with impregnated sleepers, nor is there a careful record of trials made with woods other than *Deodar*, *Sal* and *Pyingado* in their natural state. Railway Administrations have, from time to time, endeavoured to meet the rise in the prices of recognized and well-tried varieties of timber by introducing new varieties, or by artificially improving the existing ones. The experiments which have been made have not, however, met with any considerable measure of success, and it was found that these expedients could not compete economically with the well-established varieties such as *Deodar*, *Sal* and *Pyingado*.

" The Board are not aware to what extent you wish to investigate the subject, but they understand from your enquiry that you only ask for data which may be available in their office. I am, therefore, to

communicate the following particulars and to say that if further details are required, it will be necessary to refer to the Railway Administration concerned."

2. I.—Experiments carried out with impregnated sleepers.

" Omitting the *Powellizing* process which is now being tried for Railway sleepers, under the direction of the Imperial Forest Economist, experiments on Indian Railways have been practically limited to two processes (*A*) *Creosoting*, and (*B*) the *Haskin* process.

3. (A) Creosoting.

" In the infancy of Indian Railways, practice was modelled very largely on that existing in England, creosoted pine sleepers were imported to a considerable extent and were found fairly successful. In 1866 the East Indian Railway with a view to making use of certain species of soft pines and firs available in Northern India, imported a creosoting plant for the purpose of treating these sleepers. The cost of these sleepers was, however, found to be prohibitive and the plant was abandoned and sold as scrap iron many years ago.

" Creosoted pine, imported from England, continued to be used for some years by Railways having access to the western ports of India. Thus, on the North-Western Railway, some creosote pine sleepers were laid on the Kotri-Rohri section in 1897. These sleepers were *Baltic red pine* imported under I. O. Contracts No. 40-240—242, dated 23rd November 1894, and No. 48-151, dated 10th September 1895. It is believed that all these sleepers have, since 1897, been replaced by sleepers of other varieties.

" A large number of creopine sleepers were also laid on the Southern Punjab Railway previous to the year 1904 and were estimated to last from 7 to 12 years.

" The use of these imported creosoted pine sleepers has been discouraged by the Consulting Engineers to the India Office, and no sleepers of this kind have been used of recent years on State Railways. Information regarding other Railways is very scanty, but it is known that in former years the Bombay, Baroda and Central India Railway imported considerable numbers of creosoted pine sleepers ; such sleepers were also used by the Bhavnagar-Gondal-Junagad-Porbandar Railway and, to a very limited extent, by the Great Indian Peninsula Railway.

4. (B) The Haskin process.

" In November 1899, at the suggestion of the Consulting Engineer for Railways, the Government of India (Public Works Department)

circulated for remarks certain proposals for setting up installations for *Haskinizing* sleepers at a few centres. The replies of Railway officers varied considerably. While some welcomed the proposals, others anticipated that they would never lead to economy and therefore to success, and on the whole the general opinion was unfavourable to the introduction of *Haskinizing* installations in India.

" The Government of India's enquiry in 1899 elicited the information that the Bombay, Baroda and Central India and the Burma Railways already had some experience with the *Haskin* process, the particulars of which are given briefly below.

" The Bombay, Baroda and Central India Railway reported that they had recently laid some 5,000 *Haskinized* sleepers on their road, chiefly in the Bombay and Broach Divisions. The report on these sleepers was necessarily incomplete as they had only been laid a short time. It appeared, however, that after a period of about two years, the sleepers laid in the Broach Division were found to be much attacked by white-ants, and the opinion of the Engineers generally was that these *Haskinized* sleepers were inferior to *creosoted* ones.

" The Government of Burma reported in April 1901 that certain scantlings, vulcanized by the Haskin process, had been obtained and fixed on the ground at Rangoon for observation ; the results of the experiments were communicated in December 1901, and are shown in the statement attached as Appendix A. These results are not very conclusive, and nothing further seems to have been done with a view to enlarging the experiment.

" The question of the introduction of *Haskinizing* installations in India then appears to have been dropped."

2. Records of Experiments carried out in Pressure plants, subsequent to 1910.

After the laboratory and field experiments, carried out with various species of Indian timber treated in Open Tanks had proceeded up to a certain point, sufficient data were available and experience was gained to form a fair idea of the possibilities and limitations of this method of treating timber. It was found that though Indian Pines and certain softer timbers could be treated by a simple Open Tank process, the *Dipterocarps* and other harder species of timber, with possibly the exception of *Dipterocarpus pilosus*, could probably be better dealt with under pressure. At that time no pressure plant was available in India with which to carry out such tests ; so, as a commencement, a batch of sleepers of Indian timbers were sent to England to be tested. Later,

through the good offices of Messrs. The Assam Oil Co., a small experimental plant was erected at their works in Assam, while quite recently, Government have ordered an up-to-date experimental plant from Home, to be erected at the Forest Research Institute, Dehra Dun. In spite of the want of proper equipment to carry out experiments of this class, some very valuable preliminary information has been collected as to the possibility of treating Indian timbers under pressure, the results of which are given below.

(*i*) Treatment of Assam species of Timber under pressure at Digboi, Assam.

In 1914, while on tour in Assam, Mr. Hart, the Inspector-General of Forests, arranged with the Honourable Mr. A. B. Hawkins, Manager of Messrs. The Assam Oil Co., to erect a small pressure plant at their works. The necessary sleepers having been prepared and seasoned by Mr. Cooper, the Divisional Forest Officer, Lakhimpur, the writer proceeded to Assam in February 1915, to carry out the experiments. Of these sleepers, *Dipterocarpus pilosus* (Hollong) were cut between January and May 1913 and converted in June and July 1914, placed under cover in August of the same year and treated in February 1915. The timber was therefore felled two years before treatment. Moisture tests taken showed the air-dry wood to contain 27·45 per cent. of moisture at the time of treatment, while absolutely green wood of the same species was found to contain 45·37 per cent. of moisture. The *Terminalia myriocarpa* or 'Hollock' timber, was cut in June and July of 1914, the sleepers being prepared in July and August of the same year and treated in February 1915. The sleepers, therefore, had 8 months within which to season. Moisture tests showed these sleepers to contain 29·27 per cent. of moisture against 44·43 per cent. in absolutely green timber.

The primary object of the experiment was to ascertain whether *Dipterocarpus pilosus* (Hollong) and *Terminalia myriocarpa* (Hollock), timber could be treated under pressure, though other species were also included ; and, if so, the best method of carrying out the work, *i.e.*, the necessary period of treatment, the pressure required to make the timber take up the required quantity of oil, the initial vacuum if any required, the degree of seasoning necessary to allow of proper treatment and the final durability of the timber.

The plant consisted of an iron cylinder, 8 feet long and 2 feet 2 inches diameter, fitted with a removable end, the cylinder being capable of taking a charge of 7 metre-gauge sleepers and to withstand a pressure of over 200 lbs. per square inch. To the cylinder was connected pressure and

Photo.-Mechl. Dept., Thomason College, Roorkee. Photo by R. S. Pearson.

Experimental Pressure Treating plant, property of Messrs. the Assam Oil Co., Ltd., Digboi, Assam.

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vacuum pumps, the necessary gauges and a melting tank, fitted with a steam coil.

The question of the percentage of the moisture in the timber at the time of treatment being of vital importance, will be again referred to later on.

The oil used for treating the sleepers was *Green oil* and *Liquid Fuel* or *Earth oil*, mixed in equal proportions, by weight. The grade of *Earth oil* used is known as " wax drippings " and has a specific gravity of ·846, containing a high percentage of wax and an initial boiling point of 190° C. The *Green oil* used had a specific gravity of 1·095 and an initial boiling point of 221°C. The mixture commenced to boil at 190°C. and had a specific gravity of ·950. In one experiment *Earth oil* only was used.

In each case the sleepers after being charged into the cylinder were subjected to live steam for a fixed period, followed by a vacuum of upwards of 22 inches on the column of mercury. The oil heated to about 75°C., was then run into the cylinder by the vacuum suction, after which the pressure was applied, in the case of *Dipterocarpus pilosus* (Hollong), starting with the first charge at 100 lbs. per square inch, and dropping the pressure in each successive experiment until 20 lbs. per square inch was reached. In the case of *Terminalia myriocapa* (Hollock), which did not take up the oil so readily, the first charge of sleepers was subjected to 100lbs. and the last to 200 lbs. pressure per square inch. In the last experiment with " Hollong ' metre-gauge sleepers, a final vacuum was applied for an hour, in order to suck out the excess oil absorbed by the sleepers. *Bischofia javanica* sleepers were also tested, and subjected to 200lbs. pressure though, even at this pressure, poor results were obtained.

The cylinder being of very limited dimensions, it was only possible for the writer to treat relatively few sleepers so that, after having fixed the essential points, the rest of the sleepers destined to be supplied to the Railways for this experiment were treated on the same lines by Messrs. The Assam Oil Co.

The results of these experiments are tabulated below :—

TABLE XXVIII.

Experiments carried out at Digboi, Assam, to ascertain the absorption of oil by certain Assam species of timber, when treated under pressure.

Oil used in treatment.	Serial No. of experiment.	Species.	No. of metre-gauge sleepers on which the average is based.	METHOD OF TREATMENT.				Final vacuum, if any.	Average quantity of oil absorbed in lbs.	REMARKS.
				Period of steaming.	Vacuum, inches on column of mercury.	Temperature of oil.	Pressure applied.			
Green oil and *Wax drippings*, mixed in equal proportions, by weight.	I	*Dipterocarpus pilosus*, or 'Hollong' air-dried metre-gauge sleepers.	7	15 minutes at atmospheric pressure.	1 hour at 17·5 inches.	75°C.	1 hour at 100 lbs. pressure.	*Nil*	19·56 lbs. per sleeper or 13·56 lbs. per cubic ft.	The sleepers were air-dried, containing 27·45 per cent. of moisture. However, just before treatment, a sharp shower of rain fell damping the surface of the timber. On a sleeper being cut open, it was found that the oil had penetrated throughout the timber.
	II	Ditto . .	7	½ hour atmospheric pressure.	3½ hours rising to 20 inches.	78°C.	3½ hours at 10 lbs. pressure.	*Nil*	16·97 lbs. per sleeper or 11·32 lbs. per cubic ft.	Ditto
	III	Ditto . .	7	15 minutes at 20 lbs. pressure.	1 hour at 20 inches.	70°C.	½ hour at 50 lbs. pressure.	*Nil*	15·8 lbs. per sleeper or 10·53 lbs. per cubic ft.	Air-dried timber.
"C" grade Earth oil only.	IV	Ditto . .	5	Ditto .	35 minutes at 20 inches.	72°C.	Ditto .	*Nil*	17·2 lbs. per sleeper, or 11·46 per cubic ft.	Ditto

Green oil and *Wax drippings*, mixed in equal proportions, by weight.	V	Ditto . .	7	10 minutes at 12 lbs. pressure.	10 minutes at 10 inches.	76°C.	15 minutes at 20 lbs. pressure.	*Nil*	11·2 lbs. per sleeper or 7·46 lbs. per cubic ft.	Ditto
	VI	*Dipterocarpus pilosus* or 'Hollong' green sleepers.	7	15 minutes at 20 lbs. pressure	15 minutes at 20 inches.	74°C.	1 hour at 100 lbs. pressure.	*Nil*	13·3 lbs. per sleeper or 8·86 lbs. per cubic ft.	Absolutely green sleepers containing 45·37 per cent. of moisture at time of testing.
	VII	*Dipterocarpus pilosus* or 'Hollong' air-dried sleepers.	(*i*) 5 } 7	Ditto .	15 minutes at 21 inches.	76°C.	Ditto	22·5 inches for ½ hour.	(*i*) 12·7 lbs. per sleeper or 8·46 lbs. per cubic ft.	The 5 dry and 2 green sleepers were treated together. The difference in this treatment to those, the results of which are recorded above, was in applying a final vacuum, the amount of oil recovered by doing so amounting to 42 lbs., or 6 lbs. per sleeper.
		Dipterocarpus pilosus or 'Hollong' quite green.	(*ii*) 2						(*ii*) 7·7 lbs. per sleeper or 5·14 lbs. per cubic ft.	
	VIII	*Terminalia myriocarpa* or 'Hollock' air-dried sleepers.	7	Ditto .	15 minutes at 20 inches.	75°C.	Ditto	*Nil*	5·3 lbs. per sleeper, or 3·54 lbs. per cubic ft.	Air-dried timber containing 29·27 per cent. of moisture at time of treatment.
Green oil and *Wax drippings*, mixed in equal proportions, by weight.	IX	Ditto . .	7	1 hour at 20 lbs. pressure.	50 minutes rising to 21 inches.	75°C.	2 hours at 150 lbs. pressure.	*Nil*	7·2 lbs. per sleeper or 4·8 lbs. per cubic ft.	Ditto
	X	Ditto . .	5	Ditto .	1 hour rising to 21 inches.	75°C.	2 hours at 200 lbs. pressure.	*Nil*	8·6 lbs. per sleeper or 5·74 lbs per cubic ft.	Ditto
	XI	*Bischofia javanica* or 'Uriam.'	2	10 minutes at 12 lbs. pressure.	10 minutes at 10 inches.	76°C.	15 minutes at 20 lbs. pressure.	*Nil*	4 lbs. per sleeper or 2·6 lbs. per cubic ft.	Partially air-dried timber.
	XII	Ditto . .	2	15 minutes at 20 lbs. pressure.	35 minutes at 20 inches.	72°C.	½ hour at 50 lbs. pressure.	*Nil*	3·25 lbs. per sleeper or 2·17 lbs. per cubic ft.	Ditto

The conclusions arrived at from these experiments may be summarized as follows :—

(*a*) That *Dipterocarpus pilosus*, or 'Hollong' timber treats with great ease when immersed in oil and subjected to pressure. With a 100 lbs. pressure kept up for an hour (Experiment I), metre-gauge sleepers each took up 19·56 lbs. of oil, which is considerably more than is necessary. When subjected to 20 lbs. pressure for 15 minutes (Experiment V), the sleepers took up 11·2 lbs. each. The oil penetrated to the centre of the sleepers under 100 lbs. pressure and very nearly so when subjected to 20 lbs. pressure. Looking to the nature of the timber, which is very straight-grained with large pores and to the climatic conditions prevailing in Assam and parts of Bengal, where such treated sleepers are likely to be laid down, it would be advisable to treat them with anything from 9 to 12 lbs. of oil per metre-gauge sleeper or 6 lbs. to 8 lbs. per cubic foot. It is obvious that the oil will evaporate in direct proportion to the size of the pores and hence the necessity for more completely impregnating the whole tissue. To do so, it will be necessary to steam the sleepers for 10 minutes at a pressure of 10 lbs., to apply a vacuum of 10 inches for 10 minutes, to run in the oil at from 75°C. to 80°C., and apply a pressure of from 20 to 25 lbs. per square inch for 15 minutes, according to the degree of the seasoning.

(*b*) That *Terminalia myriocarpa*, or 'Hollock' requires more drastic treatment than 'Hollong,' owing to the fact that the timber is denser and harder and contains fewer pores, generally set obliquely one to the other as is characteristic of the timber of most *Terminalias*. In the experiments carried out with 'Hollock,' the absorption amounted to 5·3 lbs. with a pressure of 100 lbs. applied for one hour (Experiment No. VIII) and 8·6 lbs. per sleeper with a pressure of 200 lbs. for two hours (Experiment No. X). Probably, by increasing the time during which the pressure is applied from 2 hours to 4 hours, the impregnation could be increased to about 10 lbs. per metre-gauge sleeper while, looking to the good quality of this timber, not more than 10 lbs. per metre-gauge sleeper is considered necessary. To obtain this absorption, steaming should be carried out for one hour at 20 lbs. pressure, followed by a vacuum of 20 inches for one hour, the oil run in at 75°C. and the pressure kept at between 175 lbs. and 200 lbs., according to the degree of seasoning of timber. As an alternative to

the above procedure, as this timber is difficult to impregnate, attempts might be made to treat it by boiling in the oil under a 20 inches vacuum for 2 hours, at a temperature of 115°C., then applying a pressure of 150 lbs. for 3 hours, by doing so the treatment would probably be facilitated.

(*c*) That *Bischofia javanica*, or 'Uriam' is very difficult to treat owing to its dense nature (Experiments XI and XII). The sleepers were obtained from the Dibru-Sadia Railway Company, but their exact degree of dryness when treated was not known; they appeared, however, to be only partially seasoned. Before definitely stating that this timber is unsuitable for treatment, it would be necessary to carry out further experiments with thoroughly seasoned timber, and to treat it in the same way as is advocated for *Terminalia myriocarpa*.

(*d*) That the 'Hollong' (*Dipterocarpus pilosus*) and 'Hollock' (*Terminalia myriocarpa*) sleepers, which had been seasoning for upwards of 2 years and 8 months respectively, cannot be considered to be thoroughly air-dried, as the former contained 27·45 per cent. and the latter 29·27 per cent. of moisture. Taking into consideration the time during which these sleepers had been seasoning, it is probable that the percentage of moisture in the timber represents the degree of dryness to which the timber attains in the damp climate of Assam. No doubt the sleepers, on being placed in a well-drained and dry ballasted line, even in Assam, would dry out further, as a railway track at certain times of the year is as hot a place as can be found; nevertheless, it is thought that the additional moisture which may be lost after placing such sleepers in the line, will not be sufficient to cause excessive cracking of the timber. Were the sleepers destined for one of the Central India, United Provinces or Punjab Railways, or, in other words, to be placed in a dry, hot climate, there is little doubt that the timber would have to be further seasoned before treatment, either by artificial means or by taking it to a dry, hot climate, and allowing it to further season before treatment.

(*e*) That the treatment of green timber is altogether to be discouraged. In the first place it is more difficult to effect, as will be seen by comparing Experiments I and VI, carried out under identical conditions with air-dry and absolutely green timber; and secondly, an even more important point, ascertained from experience in Europe and America, the

timber treated green has not nearly so long a life as that treated when in an air-dry state.

(*f*) That the absorption by timber when using a mixture of creosote and Earth oil or *Earth oil* only, is practically the same. See Experiments III and IV carried out with the same wood, under similar conditions and with the above two oils.

(*g*) That oil can be recovered in considerable quantities from the timber after it has been forced in under pressure by applying a vacuum (see Experiment VII). This experiment was an extremely interesting one : it was carried out with air-dried 'Hollong' sleepers and the conditions of treatment were identical with those employed in Experiment I, except that a vacuum of 22·5 inches was applied for ½ hour, after the pressure had been released (see Experiment VII). In Experiment I, the sleepers took up 19·56 lbs. each, and in Experiment VII they took up 12·7 lbs. each, and it is reasonable to suppose that those in Experiment VII had taken up the same amount of oil as those in Experiment I before the final vacuum was applied. The actual difference in the amount of oil absorbed in these two sets of sleepers amounts to 6·86 lbs. per sleeper, while the amount of oil recovered in Experiment VII was 42 lbs. from 7 sleepers, or 6 lbs. per sleeper, and as two of the sleepers were green, and therefore gave off slightly less oil, the figure tallies remarkably well. The procedure followed in Experiment VII is that known as the "Open Cell" process, by which the fibre is first thoroughly saturated throughout with oil and the surplus oil removed by vacuum. This process differs from the "Rüping" process, which is also an "Open Cell" method of treatment, in that the surplus oil in the former process is sucked out by vacuum, while in the latter it is expelled by a cushion of air introduced before the oil is forced into the timber. It is unfortunate that no records are available in India as to the relative value of the "Open Cell" and common or "Full Cell" process of treatment, as the only country in which the "Rüping" process has been employed for any length of time is Germany, from which country, at the present time, no information is available. The "Open Cell" process has much to recommend it, especially in India where economy in oil is of paramount importance. The sleepers have been recently placed in the line near Moriani Station, and are being kept under observation.

(*ii*) TREATMENT OF INDIAN SPECIES OF TIMBER BY THE "RÜPING" PROCESS IN ENGLAND.

In order to give Indian timbers treated by the *Rüping* process a fair trial, a consignment of sleepers were sent for treatment to Messrs. Richard Wade, Sons & Co. of Hull, who hold the right to use the patent in England. The first batch received by the firm were treated in the presence of the writer, while the remainder were treated at a later date. The sleepers after treatment were returned to India to be laid in the open line and kept under observation.

The treatment consisted of raising the air pressure to 60 lbs. per square inch, after loading the sleepers in the cylinder, the *creosote* oil was then admitted from an overhead storage tank, in which the pressure was equal to that in the cylinder. On the cylinder being filled, the pressure was raised to 155 lbs. per square inch and maintained at that point for an hour. No vacuum was applied either before or after treatment, nor was the timber subjected to preliminary steaming. The process is based on the assumption that, by first introducing air in the timber, the intercellular spaces are filled with compressed air, the oil being introduced at a higher pressure is forced into the timber, driving the air before it and thus forming a cushion of compressed air which, on the pressure being released, drives out the surplus oil from the cells. That this is the case there can be no doubt, as the oil may be seen exuding from the ends of the timber after the pressure has been dropped and the timber removed from the cylinder. The results obtained by treating various species of Indian timber, according to this process, are tabulated below :—

TABLE XXIX.

Results of treating Indian species of timber according to the Rüping *process at Hull, England.*

Oil used in treatment.	Serial No. of experiment.	Species.	No. of M. G. sleepers on which the average is based.	Average quantity of oil absorbed, in lbs.	Remarks.
A good grade of coal-tar creosote.	I	*Dipterocarpus turbinatus* or 'Gurjan', from Andamans.	7	4·57 lbs. per c. ft. or 6·85 lbs. per M. G. sleeper.	Fair penetration.
	II	*Dipterocarpus tuberculatus,* or 'In', from Burma.	7	1·77 lbs. per c. ft. or 2·65 lbs. per M. G. sleeper.	Absorption probably insufficient to protect the timber.
	III	*Dipterocarpus alatus* or 'Kanyin', from Burma.	8	4·83 lbs. per c. ft. or 7·25 lbs. per M. G. sleeper.	Fair penetration.
	IV	*Dipterocarpus pilosus* or 'Hollong', from Assam.	8	5·58 lbs. per c. ft. or 8·37 lbs. per M. G. sleeper.	Penetration quite satisfactory.
	V	*Terminalia Manii,* or 'Black Chuglam', from Andamans.	7	1·77 lbs. per c. ft. or 2·65 lbs. per M. G. sleeper.	Absorption probably insufficient to protect the timber.
	VI	*Terminalia, tomentosa* or 'Sain' from Central Provinces.	8	2·125 lbs. per c. ft. or 3·19 lbs. per M. G. sleeper.	Absorption below the mark.
	VII	*Terminalia myriocarpa* or 'Hollock', from Assam.	8	2·87 lbs. per c. ft. or 4·3 lbs. per M. G. sleeper.	Ditto
	VIII	*Pinus longifolia,* or 'Chir', from the United Provinces.	4	4·87 lbs. per c. ft. or 7·3 lbs. per M. G. sleeper.	Absorption satisfactory.

In reviewing the results obtained from these experiments, it must always be borne in mind that the *Rüping* process is an "Open Cell" treatment, so that the amount of oil taken up per sleeper is somewhere about half the amount that would be taken up in the case of a "Full Cell" process. Nevertheless, the amount of oil taken up by the *Dipterocarpus tuberculatus, Terminalia Manii, T. tomentosa* and *T. myriocarpa* sleepers is probably insufficient, and that by *Dipterocarpus turbinatus* hardly sufficient. To make these timbers take up more oil, longer treatment sooner than a high pressure is recommended.

The behaviour of the sleepers treated by this process will be carefully watched as, if successful, it may be of great value to India, where economy in oil is of paramount importance.

(*iii*) Treatment of Indian species of timber by the common or "full cell" process.

In 1914, the question of treating certain Andaman *Dipterocarps* came under consideration, and, in order to ascertain whether *Dipterocarpus turbinatus* would lend itself to treatment, no pressure plant existing at that time in India, a batch of sleepers were sent to England to be tested. The work was carried out by Messrs. George Black & Sons, Creosoting

Engineers at Berwick-on-Tweed. The sleepers treated consisted of 50 metre-gauge sleepers and 46 broad gauge sleepers, 3 broad gauge sleepers in addition having been treated after having been cut in half for preliminary experiments. These initial tests with the six half-sized broad gauge sleepers gave the following results :—

TABLE XXX.

No. of specimen.	Weight before treatment, in lbs.	Weight after treatment, in lbs.	Difference in weight, in lbs.	Absorption per cubic foot, in lbs.	Pressure in lbs. per sq. inch.	Duration of treatment, in minutes.	REMARKS.
A 1	99·5	108	9·5	5·8	100	30	Hardly sufficient.
A 2	94·5	105·5	11	6·7	100	30	
B 1	99·5	109·5	10	6·1	125	30	
B 2	95	106	11	6·7	125	30	
C 1	86	98·5	12·5	7·6	150	30	Sufficient.
C 2	87	101·5	14·5	8·8	150	30	

The above trial lot having been treated, in order to ascertain the lines on which the rest should be treated, the other sleepers, referred to above, were all treated at 150 lbs. pressure for 3 hours with the following results :—

TABLE XXXI.

No. of sleepers treated.	Total weight before treatment.	Total weight after treatment.	Difference in weight, in lbs.	Absorption per cubic foot, in lbs.	REMARKS.
	Tons. cwt. qrs.	Tons. cwt. qrs.			
50 M. G. sleepers.	1 18 3	2 3 3	560	7·5	Sufficient.
46 B. G. sleepers.	4 2 0	4 10 3	980	6·8	It would be well to keep the figure well over 7 lbs. per c. ft. by prolonging the period to 4 hours.

The firm, in their report, state that they split one large and one small sleeper through the middle and found the results satisfactory, creosote being traced right through the sleepers. They also had a portion of the timber taken from the centre of one of the half sleepers analysed and found it contained creosote. From these experiments it is clear that this species of timber presents no difficulty in treatment.

The treated sleepers were returned to India and handed over to the Eastern Bengal State Railway. They were laid in the open line in June 1915 under the following conditions :—

TABLE XXXII.

Record of experimental sleepers treated under pressure by Messrs. George Black & Sons and laid for experimental purposes in the Eastern Bengal State Railway.

Species.	No. of sleepers laid down.	Locality where laid down.	Date of laying down.	Date of last inspection.	Inspection notes.	Remarks.
Dipterocarpus turbinatus from Andamans.	46 B. G. sleepers.	Between Naihati and Kankinara, Down line mile 22, Telegraph posts Nos. 22/18 to 22/19.	18th June 1916.	23rd June 1917.	None removed up to date. Their condition is as good as the day they were laid in the line, except that slight surface cracks have developed. On the under surface they are perfectly sound. Inspected by Mr. Taylor, Sub-Divisional Officer, and Forest Economist.	D. C. T. cut on top of each sleeper.
Ditto	46 M. G. sleepers.	Between Phulbari and Bhowanipur, mile 101, Telegraph posts Nos. 101/19 and 101/21.	15th August 1915.	January 1917.	The sleepers are in good condition, the rail-seats do not appear to have been damaged and the screw-spikes are all very firm still. The sleepers in appearance are very like Sal sleepers and appear to be as hard. Some of them have developed slight longitudinal cracks, but in this respect also I do not think they are any worse than Sal sleepers. It is impossible to say yet whether they will turn out as good as or better than Sal in the long run. Inspected by the Executive Engineer, Saidpur District.	Z. X. V. stamped on each sleeper.

(*iv*) SLEEPERS OF INDIAN TIMBERS CREOSOTED AT THE INSTIGATION OF MESSRS. MILLAR'S TIMBER AND TRADING CORPORATION.

The writer is indebted to the above firm for the following information. In 1911 Messrs. Millar's Timber and Trading Corporation sent 6 sleepers of *Abies Pindrow* (Silver fir), *Picea Morinda* (Spruce), *Pinus longifolia* (Chir), and *Pinus excelsa* (Kail) to England to be creosoted. The sleepers, after treatment, were returned to India and handed over to North-Western Railway to be laid in the line.

The report of the Engineer, who supervised the treatment on behalf of the firm, states that the creosote employed had a specific gravity 1·070 to 1·076, 75 per cent. distilling over at 610°F., Tar acids 8—10 per cent. The treatment consisted in subjecting the sleepers to a pressure of 95 lbs. per square inch, the temperature of the oil being maintained at 75°C. The results were as follows :—

Species.	Weight per cubic foot, untreated.	Absorption, 2 hours treatment, in lbs. per cubic foot.	Absorption, 6 hours treatment, in lbs. per cubic foot.
	lbs.	lbs.	lbs.
Silver fir . . .	33·3	2·54	3·15
Spruce	30·7	1·58	2·5
Chir pine	47·2	7·32	8·47
Blue pine	34·5	1·01	1·51

On cutting open the sleepers, it was found that, at 6″ and 18″ from the ends, the penetration in the case of 'Silver fir,' 'Spruce' and 'Blue pine' was unsatisfactory and incomplete. The 'Chir' pine, however, showed good absorption, with the whole area impregnated at mid-length.

The sleepers on being returned to India were laid in the line, and the latest information from inspection reports is given below :—

TABLE XXXIII.

Record of experimental sleepers of Indian Timbers, creosoted by Messrs. Millar's Timber and Trading Co., laid down in the North-Western Railway.

Species.	No. of sleepers laid down.	Locality where laid down.	Date of laying down.	Date of last inspection.	Inspection notes.
Abies Pindrow, 'Silver fir.'	6 B.G.	Ranipur Station, mile 261/89 N. W. Railway.	22nd March 1912.	22nd April 1917.	Four having been found heavily damaged by white-ants were removed from the road in December 1916. Two left now are alright. Slight tendency to cut under the bearing-plate.
Picea Morinda, 'Spruce.'	Do.	Do.	Do.	Do.	One was removed previously having badly cracked. Four were removed in December 1916 having been eaten by white-ants, the last now removed badly damaged.
Pinus longifolia, 'Chir.'	Do.	Do.	Do.	9th October 1914.	General condition good. Spikes on bearing-plates holding well. No white-ants. There is a marked tendency to warp ; while the small surface cracks which have appeared are of no account. There is a slight tendency for the bearing-plate to cut into the seat.
Pinus excelsa, 'Kail.'	Do.	Do.	Do.	Do.	Very good condition generally.

The silver fir and spruce have been heavily attacked by white-ants, due no doubt to the very small quantity of oil they absorbed during treatment.

(v) Record of Creopine sleepers laid in the Bengal and North-Western Railway.

In 1906-07, the Bengal and North-Western Railway laid down at mile 27 of the Mansi-Bhaptiahi Extension of their system, a consignment of creosoted pine obtained from Europe. The exact species of pine

which was employed is not known, but it probably came from Norway. In 1912, that is after 6 years, after a careful examination it was found that 34 per cent. of them required almost immediate renewal. The Chief Engineer was in consequence obliged to report adversely upon these sleepers, the cause of rejection being due to a combination of rot, white-ant attack and mechanical wear and tear.

No details are available as to the method of treatment or of the quality of the oil with which the sleepers were injected, which robs the experiment of a great deal of its value.

(*vi*) CONCERNING A LARGE CONSIGNMENT OF CREOSOTED DOUGLAS FIR SLEEPERS FROM BRITISH COLUMBIA PURCHASED BY THE BENGAL AND NORTH-WESTERN RAILWAY COMPANY.

One of the largest consignments of treated sleepers as yet purchased by any Indian Railway, was that of 160,000 creosoted *Douglas Fir* which took place in 1914. Details of this consignment were given by the Chief Forester, Forest Branch (Lands Department), Victoria, British Columbia, in a letter dated 8th October 1914 to the Honorary Editor of the *Indian Forester* and, in order to describe the method of treatment, and the specifications under which these sleepers were to be supplied, we cannot do better than quote the letter *in extenso* :—

"A cargo of 160,000 creosoted *Douglas Fir* sleepers were recently sent from British Columbia to India. This shipment constitutes a trial order placed in British Columbia, by the Bengal and North-Western Railway Company, for the purpose of testing creosoted *Douglas Fir* sleepers in service in India.

"The specifications governing the grades of timber to be accepted, the grade of oil to be used, and the manner of treatment were furnished by the Bengal and North-Western Railway Company. The important features of the specifications were :—

1. The sleepers were to be of the best quality *Douglas Fir*, well-seasoned, perfectly sound, sawn from logs cut within two years, free from sap-wood, rotten wood, or materially depreciating shakes, wanes and large or loose knots.
2. No waney edges were allowed.
3. The treatment should ensure an absorption of 12 pounds of *creosote* per cubic foot.
4. The *creosote* should conform to the following specifications :—

Completely liquid at 38°C.

Specific gravity at 38°C.—1·03.

Only 8 per cent. by volume of tar acids to be soluble in caustic soda solution.

No distillate below 200°C., not over 5 per cent. below 210°C., not over 25 per cent. below 235°C., and the residue 355°C., if it exceeds 5 per cent. in quantity, should be soft.

" The inspection of the timber and of the creosoting operations was carried out by the Provincial Forest Branch. The sleepers were cut from sound *Douglas Fir* logs felled within the preceding twelve months. No sleepers with shakes, splits, loose or large knots sap-wood or defective wood were passed for treatment.

" The sleepers were creosoted immediately after being sawn.

" English oil was used, the specific gravity at 38°C. being 1·04, 13 per cent. by volume of tar acids extracted at 38°C., no distillate at 200°C., 1·2 per cent. at 210°C., 11·2 per cent. at 235°C., and a soft residue comprising 22 per cent. of the total volume remaining at 355°C.

" The sleepers were treated under a pressure process, remaining under pressure for six hours at a temperature of 125°F. and a pressure of 5 lbs. at the beginning of this period, and 180°F. and 85 lbs. at the end of the period. The sleepers were under treatment 30 hours, and in the creosote bath 24 hours.

" The average absorption of creosote per cubic foot was 12·03 lbs. The penetration of oil at the centre of the sleepers averaged over one inch in depth. The penetration from the end of the sleeper parallel to the grain was very much greater.

" The specification did not call for the boring of sleepers for spikes before treatment. The spike holes would greatly increase the penetration of creosote under the rail and strengthen the sleeper against decay at the weakest point, the rail-seat. Should any further trials be made of creosoted *Douglas Fir* sleepers, a point should be made of boring the sleepers before treatment.

" Constant improvements are being made in the method of creosoting *Douglas Fir*. A study of the service rendered by this shipment may indicate further changes to be made in the process of treatment, the quantity of oil used or the grade of wood to be accepted for treatment. A supply of cheap structural timber stands in British Columbia awaiting markets. We know that it can be given a preservative

treatment which will fit for tropical use as railroad sleepers or in structural works. It is only necessary that a study should be made of the requirements of India, in order that British Columbia may be in a position to fill those requirements.

"The sleepers have only been recently laid in the line; so, at present, they tell us nothing, their behaviour in future years will be watched with considerable interest."

(3) Conclusions, based on the above Experiments.

The experiments carried out in India in recent years, with sleepers treated under pressure have, with the exception of a few creosoted sleepers, laid in the North-Western Railway and Creopine laid in the Bengal and North-Western Railway, all been in progress so short a time that no data as to the durability of the sleepers are available. The creosoted 'Silver fir,' 'Spruce,' 'Chir' pine and 'Blue' pine, laid in the line four years ago are in fair condition, while the Creopine have shown a life of six years only, which is not satisfactory.

The Assam experiments show that *Dipterocarpus pilosus* timber treats without any difficulty, but that *Terminalia myriocarpa* will require special treatment even to make it take up 6 lbs. to 8 lbs. of oil and *Bischofia javanica* is obviously difficult to treat under any conditions. Of the sleepers sent to Europe for treatment, *Dipterocarpus turbinatus* from the Andamans, *D. alatus* from Burma, *D. pilosus* from Assam, and *Pinus longifolia* from the United Provinces, all gave excellent results, while *Dipterocarpus tuberculatus* from Burma, *Terminalia Manii* from the Andamans, *T. tomentosa* from the Central Provinces and *T. myriocarpa* from Assam all showed reluctance to take up the oil, and though most of them can probably be dealt with satisfactorily, they will require special treatment to make them take up the required amount of creosote.

A sufficient number of sleepers of these species of timber have now been laid down by the Railways of India, to assure definite data being obtained in years to come as to their value when treated by the various processes described above.

PART VI.

FACTORS GOVERNING THE TREATMENT OF TIMBER.

(1) General.

It is necessary to deal separately with each factor on which the successful treatment of Railway sleepers depends, as they vary widely

one from another, though they are in most cases entirely dependent one on the other; thus the mechanical strength of the timber does not affect the cost of treatment though, unless both fall within the required specification, such an undertaking is doomed to failure. That the treatment of timber is not always a simple matter, has not been sufficiently recognized in this country, and is without doubt one of the causes of failure in the past. In the following chapter it is proposed to deal with each factor separately, with due regard to their bearing one to another.

(2) Species of timber suitable for Railway sleepers, after treatment.

On pages 11 and 12 of Volume III, Part II, of the *Indian Forest Records*, is given a list of timbers, divided into three classes which, it is thought, might be utilized for sleepers after treatment. Further information as to possible supplies of timber has been collected since that list was prepared, while the results of recent experiments have made it possible to add several new species of timber to those previously mentioned. The lists, as they now stand, are as follows :—

I. Timbers which are most likely to fulfil the necessary requirements.	1. *Dipterocarpus tuberculatus.* 2. ,, *alatus.* 3. ,, *turbinatus.* 4. ,, *pilosus.* 5. *Shorea assamica.* 6. *Terminalia tomentosa.* 7. ,, *myriocarpa.* 8. ,, *Manii.* 9. ,, *paniculata.* 10. *Pinus longifolia.* 11. *Abies Pindrow.* 12. *Picea Morinda.*
II. The next most likely species to fulfil the necessary requirements.	13. *Altingia excelsa.* 14. *Anthocephalus Cadamba.* 15. *Vateria indica.* 16. *Terminalia Catappa.* 17. ,, *bialata.* 18. *Bischofia javanica.* 19. *Lagerstrœmia microcarpa.* 20. ,, *Flos-Reginæ.* 21. ,, *parviflora.* 22. ,, *tomentosa.*
III. Possible sleeper woods	23. *Pinus Khasya.* 24. *Pœciloneuron indicum.* 25. *Albizzia Lebbek.* 26. ,, *odoratissima.* 27. *Hardwickia binata.* 28. *Vitex altissima.* 29. *Callophyllum Inophyllum.* 30. *Dillenia indica.* 31. *Artocarpus Chaplasha.* 32. *Manglietia insignis.* 33. *Cynometra polyandra.*

The most important alteration made to the former list consists in excluding *Pinus excelsa* from the first class, not because the timber is unsuitable, but on account of the demand for this timber for constructional purposes. *Dipterocarpus pilosus, D. turbinatus, Shorea assamica, Terminalia myriocarpa, T. Manii and T. paniculata* have been added to class I, partly on account of the supplies being considerable and also because recent tests have demonstrated the possibility of treating these timbers, while their mechanical strength is sufficient to withstand the wear and tear to which sleepers are subjected. The most noticeable additions to the first class are *Abies Pindrow* and *Picea Morinda*, the 'Silver fir' and 'Spruce,' respectively, the supplies of which from the Punjab forests are very considerable. A point about which doubt might be expressed in classifying these two timbers under list I, is in respect to their mechanical strength and resistance to absorb an antiseptic. In justification of such a classification, it may be said that in strength 'Spruce' equals, if it does not exceed, that of 'Douglas Fir,' which, after treatment, is commonly used in Canada andAmerica for sleepers, while 'Silver fir' is little inferior to that species. As regards treatment, the tests carried out in England, which are corroborated by laboratory tests in India, show these two species to be extremely difficult to treat; on the other hand, 'Douglas Fir' is equally difficult to treat, so there seems little reason to doubt that the special process adopted in treating the latter species may answer equally well with 'Silver fir' and 'Spruce.'

Class II has lost some species at the expense of class I; on the other hand, *Altingia excelsa, Anthocephalus Cadamba, Vateria indica, Terminalia bialata, Mesua ferrea and Dillenia indica* have been added to it.

Class III could, no doubt, be very much increased, consisting as it does, chiefly of timbers which might easily be placed in class I, were they either available in larger quantities or were not already in such demand for other purposes that their market value in some parts of India is already beyond that of sleeper woods.

The above lists have been prepared after taking into consideration the most important factors upon which depends the possibility of using the timber, after treatment, for Railway sleepers. The essentials are (1) that the available supply should be large, (2) that the cost of the timber as a suitable treating plant be not excessive, (3) that the timber be of sufficient strength for the purpose, and (4) that it should yield readily to treatment.

It is not likely that all the timbers mentioned, or even those in class I, will come into use in the near future. It is, however, possible to indicate which of them are likely to receive prior attention, chiefly on account of

the available supply and cheapness of extraction. Thus *Pinus longifolia* sleepers—the 'Chir' pine of the Lower Himalayas—has already been treated in considerable numbers and is being supplied to State Railways. The other more likely sleepers which deserve early attention may be divided into two groups: first, the Andaman timbers including *Dipterocarpus turbinatus, D. alatus, Terminalia Manii, T. bialata, T. Catappa,* and the Himalayan 'Spruce' and 'Silver fir'; and secondly, the Assam species consisting of *Dipterocarpus pilosus, Shorea assamica, Terminalia myriocarpa,* possibly *Altingia excelsa* and others. Any Railway Company or private firm considering the question of treating sleepers, would do well to consider the possibility of starting work in either one or other of these localities. It might with justice be asked why the great variety of fine timbers found in the Burma forests are not included. The reason is that labour is expensive and not over-plentiful in Burma and that most other considerations are at present overshadowed by the trade in teak timber, though there is not the least doubt that Burma stands easily first as regards its future possibilities.

(3) The mechanical strength and seasoning qualities of timbers suitable for sleepers.

(*i*) Mechanical properties.

From inspections made of the treated sleepers in the line, it seems fairly certain that the timbers of *Pinus longifolia, P. excelsa, Abies Pindrow,* and *Picea Morinda* are not sufficiently tough to withstand the cutting action of the foot-rail, and that they will require to be fitted with bearing-plates.

In the case of the four *Dipterocarps* and *Shorea assamica* mentioned in list I, provided the traffic is light or moderately so and the foot-rail fairly broad, it will probably not be found necessary to use bearing-plates, whereas if the traffic is heavy, they will be necessary.

As regards *Terminalia tomentosa, T. myriocarpa* and *T. Manii,* all of which are hard timbers, it is thought that no bearing-plates will be necessary.

The tendency of the dog-spike to enlarge the spike holes has also to be considered. While inspecting the various lots of treated sleepers, several of the spikes were drawn in order to ascertain whether or not they showed any tendency to shake loose and, in no instance, was this found to be the case. The spikes were found to be holding moderately well in the case of the *Pine* sleepers, well in the case of the *Dipterocarps,* while the *Terminalia tomentosa* sleepers held the spikes so strongly that they could only be removed with difficulty.

The power of certain Indian timbers to withstand a direct pull applied to a dog-spike driven into the sleeper, has recently received attention and tests have been carried out in this connection in the Forest Economist's workshops at Dehra Dun. The machine employed in carrying out these tests is of the usual type used for carrying out tests for transverse, compression and shearing strain, the only alteration necessary being a specially devised clutch to hold the head of the dog-spike. The results obtained are strictly comparable, as they were carried out on similar lines. Some of these results, to illustrate the power of various timbers to withstand spike pull, are given below :—

TABLE XXXIV.

The figures given below are average of four tests in each case.

Species.	Method of driving spikes.	Direct pull in lbs., required to withdraw dog-spikes, being the average of 4 tests.	REMARKS.
Cedrus Deodara	Hole bored $\frac{3}{8}''$ right through sleeper and spike driven home.	4,315	Spikes released suddenly.
Ditto	Hole bored $\frac{1}{2}''$ right through sleeper and spike driven home.	3,791	In some cases the spikes released suddenly, in others slowly.
Ditto	Hole bored $\frac{5}{8}''$ right through sleeper and spike driven home.	2,770	Spike released somewhat slowly.
Ditto	Hole bored $1\frac{1}{2}''$ deep with $\frac{3}{8}''$ augur and spike driven home.	3,807	Spikes released suddenly.
Ditto	Hole bored $1\frac{1}{2}''$ deep with $\frac{1}{2}''$ augur and spike driven home.	3,959	Ditto
Ditto	Hole bored $1\frac{1}{2}''$ deep with $\frac{5}{8}''$ augur and spike driven home.	3,709	Spikes released somewhat slowly.
Shorea robusta	Hole bored $\frac{3}{8}''$ right through the sleeper and spike driven home.	5,315	In one case spike released somewhat slowly. In other cases spikes released suddenly.
Ditto	Hole bored $\frac{1}{2}''$ right through the sleeper and spike driven home.	5,352	In one case spike released suddenly. In other cases spikes released somewhat slowly.

TABLE XXXIV—*contd.*

The figures given below are average of four tests in each case—contd.

Species.	Method of driving spikes.	Direct pull in lbs., required to withdraw dog-spikes, being the average of 4 tests.	Remarks.
Shorea robusta .	Hole bored ⅝″ right through the sleeper and spike driven home.	5,155	Spikes released somewhat slowly.
Ditto .	Hole bored 1½″ deep with ⅜″ augur and spike driven home.	4,366	In one case spikes released suddenly. In other cases spikes released somewhat slowly.
Ditto .	Hole bored 1½″ deep with ½″ augur and spike driven home.	4,156	Ditto
Ditto .	Hole bored 1½″ deep with ⅝″ augur and spike driven home.	3,869	Spikes released somewhat slowly.
Pinus longifolia or 'Chir' *Powellized* old sleeper, having been 3 years in the line.	Hole bored ½″ through sleeper, and spike driven home.	3,038	The spike released slowly.
Dipterocarpus alatus	Hole bored ⅜″ and 1½″ deep, spike driven home.	8,210	Spike released slowly.
Ditto	½″ hole bored through sleeper and spike driven home.	6,202	Ditto
Ditto	⅝″ hole bored through sleeper and spike driven home.	5,587	Ditto
Dipterocarpus tuberculatus.	Hole bored ⅜″ and 1½″ deep, spike driven home.	8,315	Spike released suddenly.
Ditto	⅝″ hole bored through sleeper and spike driven home.	8,345	Spike released slowly.
Ditto	Ditto	6,765	Ditto
Dipterocarpus pilosus.	Hole bored ⅜″ and 1½″ deep, spike driven home.	6,870	Ditto
Ditto	½″ hole bored through sleeper and spike driven home.	5,575	Ditto
Ditto	⅝″ hole bored through sleeper and spike driven home.	5,030	Ditto
Silver fir . .	No hole bored previous to driving spike.	1,993	Ditto
Spruce . . .	Ditto	2,477	Ditto

(*ii*) SEASONING OF SLEEPER WOODS.

(*a*) *General discussion of the subject.*

It is difficult to lay sufficient stress on the importance of seasoning timber before treatment, for unless proper care is taken in this respect any undertaking of this nature will be doomed to failure. In making the above very definite statement, such processes as *Haskinizing* must be excluded as, in this process, the saps in the timber are sterilized and made use of for preserving the fibre. The reasons for only using seasoned timber for treatment are that (*i*) the inclusion of large quantities of moisture in the timber, by partial impregnation of the fibre, results in the premature decay of the tissue ; (*ii*) the smaller the amount of sap and nutritious substances left in the timber, the less liable is it to fungus and insect attack ; (*iii*) the impregnation of the timber with an antiseptic in *Open Tanks* and to a somewhat less extent when treated under *Pressure,* becomes in direct proportion more difficult as the percentage of moisture in the timber increases ; (*iv*) unseasoned timber is liable to develop cracks owing to the rapidity of seasoning when placed in the line ; this is a factor of paramount importance in the case of Indian timbers, exposed to Indian conditions of climate ; and lastly, (*v*) that seasoned timber, even in an untreated state, lasts longer than unseasoned timber.

The second point raised is a corollary of the first, and they both concern decay. For decay to take place in timber, moisture, air, light and warmth are necessary. Provided the timber does not crack, moisture and air are excluded from the outer surface of a sleeper by the shell of treated tissue. As soon as a fine crack penetrates through the outside layer of treated timber, air and light are admitted and provided the internal layers of timber in the sleepers still contain much moisture, the conditions necessary to fungus growth are present, hence the necessity for seasoning the timber before treatment.

The third point refers to penetration of the antiseptic. That an oil or salt will penetrate seasoned timber more readily than unseasoned timber is fairly obvious ; for, in the former state, the cells are more open than when filled with sap. In practice, if a piece of timber is treated green, on being cut open it will be seen that the distribution of the antiseptic oil is in streaks or patches and in any case is very irregular, due to the presence of moisture which has stopped penetration in places and not in others, whereas if the wood be seasoned the penetration is deeper and much more uniform.

The next point refers to the liability of unseasoned timber to crack to a greater extent than does seasoned timber. This is a most important

point, as not only has it been found necessary to prematurely reject many sleepers after they have been in the line a short time, due to excessive cracking, but in many cases the conversion of sleepers from green logs has resulted in excessive splitting, resulting in rejection before treatment. As an example in point, it may be stated that some of the *Dipterocarp* sleepers prepared in Burma and destined for experimental purposes, were cut from green logs, resulting in upwards of 70 per cent. rejections before treatment, whereas those prepared afterwards to make up the deficit were cut from seasoned logs, of which not 4 per cent. had to be rejected.

A further lesson in connection with the splitting of timber can be learnt by examining the experimental sleepers treated with different antiseptics, which have been laid down in the line during the last six years. It only requires a superficial inspection of any of these sleepers, and especially of those which have been for upwards of 6 years in the line, to see that the treatment has, in nearly every instance, protected the fibre from decay and that the real danger, when it exists, is due to excessive cracking. Some of these sleepers were very thoroughly seasoned, others only partially so, as at the time that the experiments were carried out, the importance of employing only thoroughly seasoned timber was not fully realized.

(*b*) *Percentage of moisture in timber.*

This brings us to the question of the percentage of moisture in the timber, that is, to a definition of what is meant by "air-dry" timber. In Europe and in the temperate climate of North America, where the minimum percentage of humidity in the air is considerably in excess of the minimum in the dry zones of India and where the temperature is far below that of the Peninsula or of Northern India, air-dried timber contains anything from 15 per cent. to 30 per cent. of moisture. In the hot weather, in the dry zones of India, seasoned timber contains from 8 per cent. to 15 per cent. of moisture, according to the species. In the damper climates, such as exist in parts of Burma, Assam, Bengal and the West Coast, seasoned timber rarely contains less than 18 per cent. to 25 per cent. of moisture. Thus, the experimental *Dipterocarpus pilosus* sleepers, dealt with in the Digboi experiments, which were treated 2 years after conversion, contained as much as 27 per cent. of moisture, for the reason that Assam possesses a damp climate. On the other hand, when testing timber at Dehra Dun, which has a fairly dry climate for 7 months of the year, with a temperature rising to 105°F. in May and June, no tests are carried out unless the timber contains under 15 per

cent. of moisture. In Central India, the Punjab and Rajputana, where temperatures run high and the moisture in the air is very low during the dry season, the percentage of moisture in timber falls below 10 per cent. It is therefore impossible to lay down a hard and fast rule as to what should be considered to be " air-dry timber." Provisionally, it may be laid down that sleepers destined to be placed in dry, hot localities should not be treated if containing more than 15 per cent. of moisture and in wet localities not more than 25 per cent. of moisture.

By accepting the principle that timber must be seasoned to a point commensurate with the degree of moisture and heat to which it will be subjected after treatment, the question of how best to season the timber must be considered. In the dry zone areas of India, there is generally no difficulty whatsoever in reducing the moisture in timber below 15 per cent.; on the other hand, the process of seasoning is often so rapid that serious cracks develop in the timber, and it is only by protecting the timber from the direct rays of the sun that such defects can be reduced to a minimum. It is in the damper localities, such as the West Coast, parts of Bengal and Burma, in Assam, and in the Andamans that special measures may have to be taken to reduce the percentage of moisture in the timber and to hasten the process of seasoning. Natural seasoning in such localities will hardly reduce the moisture in the timber to 25 per cent., except perhaps for a short period during the hot weather. The prevailing conditions, therefore, point to the necessity for artificial seasoning of the timber. This is generally a somewhat costly process, and one which requires a certain amount of skill. Many patent plants exist which have been designed for seasoning timber such as, for instance, the Sturtevant or Erith's processes. It is thought that to season sleeper woods entirely in such plants would not be practicable, as the amount of timber to be handled would be very considerable, though it may be found profitable to use such plants to finish off the seasoning process, after natural seasoning has reduced the moisture in the sleeper as far as is possible.

(c) *Steam, Vacuum and Oil seasoning experiments.*

In Europe and America, and especially in the latter continent, timber is sometimes seasoned either with the help of steam and vacuum or by boiling in oil. To ascertain to what degree of dryness certain Assam species of timber could be seasoned by these methods, the writer carried out experiments in February 1916, at Digboi, in the same treating cylinder as was used the previous year for treating the sleepers. Details of

the methods employed in carrying out these experiments are given below :—

Experiment I.—Steam and Vacuum seasoning.

This experiment was carried out with the object of determining whether absolutely green sleepers of Hollong (*Dipterocarpus pilosus*), could be seasoned by hot steam, as described in Weiss's work on timber treatment.

The experiment was carried out in the plant referred to previously. The procedure followed was to charge the cylinder with four absolutely green "Hollong" sleepers, which were weighed before being treated. The sleepers were subjected to live damp steam for 2 hours, the temperature being gradually raised by the heating coil to 230°F., the pressure at that time being 10 lbs. After this the steam was cut and a vacuum corresponding to a column of 20 inches of mercury was applied for ½ hour, the temperature being lowered to 190°F. During this process a certain amount of sap was extracted, but as the sleepers had only lost an average of 3·25 lbs. each, it was decided to continue the process on more drastic lines. They were therefore again put into the cylinder, and subjected to a further bath of live steam for 4 hours, at 20 lbs. pressure, and a temperature of 250°F. After this a vacuum of 20 inches was applied for ¾ hour, the temperature being 187°F. The results are summarized below :—

TABLE XXXV.

Sleeper No.	Weight before treatment, in lbs.	Weight after treatment, in lbs.	Loss of weight, in lbs.	Total duration of steaming.	Maximum temperature.	Maximum pressure.	Total duration of vacuum.	Maximum vacuum.	Maximum temperature, during vacuum.
V	90	81·0	9·0	6 hours.	250°F.	20 lbs.	1¼ hours.	20″	187°F.
VI	107·5	95·5	12·0						
VII	90	81·5	8·5						
VIII	94	84	10·0						
Average	95·4	85·5	9·9						

The sleepers treated were of metre-gauge size and therefore contained 1·5 cubic feet of timber, a cubic foot of which weighed 63·6 lbs. green and 57 lbs. after steam-seasoning. Gamble gives the weight of air-dried 'Hollong' as 43 lbs. per cubic foot; steam-seasoning, therefore,

had only reduced the amount of moisture in the timber to about one-third the necessary amount. The sleepers were examined after treatment and were found to have developed numerous small surface cracks. On examination of the interior of the timber the tissue was found to be quite wet, though the pores, which are large and numerous in this species, were free from sap on the end section.

Experiment II.—Oil-seasoning.

The same plant, with the addition of a condenser pipe, was used in carrying out the oil-seasoning experiment. The cylinder was charged with metre-gauge 'Hollong' sleepers, in an absolutely green state. Hot oil was run into the cylinder, leaving a vacant space at the top, though submerging the sleepers. The heating coil was started at 9 A.M. and the oil gradually raised to 223°F. by 1 P.M., by which time 1¾ gallons of sap had distilled over. By 4 P.M., that is, 7 hours after heating commenced, 4¾ gallons of sap had been collected. As, by this time, the condenser flow was much reduced, the heating operation was stopped, the cylinder was filled with oil and a pressure of 15 lbs. applied for 15 minutes. When running off the oil it was found that a little over 2 gallons of sap had collected in the cylinder, due to condensation of the vapours against the inside top of the cylinder. It might be contended that this was not sap, but as no live steam had been introduced, while the amount of water in suspension in the oil could also not possibly account for more than a pint at most, it is certain that this accumulation could be nothing but condensed sap. It is therefore necessary to add these two gallons, so collected, to the 4¾ gallons collected from the condenser pipe, in all 6¾ gallons.

The results may be summarized as follows :—

TABLE XXXVI.

Sleeper No.	Weight before treatment, in lbs.	Weight after treatment, in lbs.	Difference, in lbs.	Heating period.	Amount of sap collected.	Duration of pressure.	Pressure applied.
I	93·5	99	+0·5	7 hours.	6¾ gallons.	15 minutes.	15 lbs.
II	96	100	+4·0				
III	101	100	—1·0				
IV	94	97	+3·0				
TOTAL	389·5	396	+6·5				
AVERAGE	97·4	99	+1·6				

From the above statement it will be seen that the four sleepers have increased in weight by $6\frac{1}{2}$ lbs., while they have lost $67\frac{1}{2}$ lbs. of sap, assuming that the specific gravity of sap is 1. The amount of oil, therefore, which they have absorbed is 74 lbs. or 18·5 lbs. per sleeper. The average weight of a green sleeper was 97·4 lbs.; deducting 1·69 gallons of sap lost by one sleeper during treatment, its weight would be 80·5 lbs., leaving out of consideration the amount of oil absorbed. As a metre-gauge sleeper is 1·5 cubic feet, the weight per cubic foot after treatment amounts to 53·6 lbs., while air-dried 'Hollong' weighs 43 lbs. per cubic foot. To complete the seasoning of the sleepers it would, therefore, be necessary to take out another gallon of sap per c. ft. The sleepers were examined and found to be not cracked after treatment.

Conclusions.

Taking into consideration that the above experiments were only carried out with relatively few sleepers, they are not final. Provisionally, the following conclusions have been arrived at :—

1. That partial seasoning can be obtained by either steam or oil seasoning, but that the process is in both cases incomplete.
2. That oil seasoning gives better results than steam seasoning as, by the former process, the four sleepers lost a total of 39·6 lbs., while those treated in hot oil lost 67·5 lbs. by weight.
3. That were the oil seasoning process to be prolonged at a slightly higher temperature, the point of seasoning reached might be sufficient for sleepers used in the damp climate of Assam, but not for dry hot situations.
4. That the above experiments having been carried out on a very small scale, they cannot in any way be accepted as final.

From what has been said above, it will be gathered that there are two possible ways of dealing with the question of seasoning timber before treatment in damp climates : (*i*) to naturally season as far as possible and finish off the process in drying kilns, or (*ii*) to season in oil in conjunction with treatment. Until further data are available, no definite statement can be made as to the relative merits of these two processes when working under Indian conditions, though probably the former process would be the safer of the two to adopt under existing circumstances.

(4) Discussion as to the most suitable method of treating timbers.

When considering the best method to be adopted for the treatment of timber, we have first to take into consideration the species of timber

to be treated, the size and shape of the timber and the quantity to be dealt with. On these three factors will depend whether we adopt the *Brush*, *Open Tank* or *Pressure* processes. When a relatively small quantity of timber, say, for instance, a few hundred fencing posts, or constructional timber for a small bungalow has to be handled, application of two or more coatings of the antiseptic with a brush may suffice. In the event of a larger number of posts, telegraph poles, bridging or constructional material or from 30,000 to 50,000 sleepers having to be treated, the timber of which readily absorbs an antiseptic, an *Open Tank* plant may best answer the purpose ; while, for large quantities of sleepers, the timber of which does not readily absorb the antiseptic and where the plant is of a permanent nature, a pressure plant is advocated.

The amount of the antiseptic to be introduced also requires consideration when deciding between *Open Tank* and *Pressure plants* ; thus, if 6 lbs. or more per cubic foot is the amount specified, unless the timber is especially absorbent, a Pressure plant will be required.

(5) Choice of Antiseptics.

With a view of determining the most suitable antiseptic for general use in India, the experiments detailed in Parts III, IV and V have been started. The choice of treatment may be said to lie between (*i*) *Powellizing*, (*ii*) *Coal-Tar creosotes*, patent or otherwise, (*iii*) mixed *Coal-tar creosotes* and *Petroleum* products, (*iv*) *Salts*, such as *Chloride of Zinc*, *Atlas*, *Fluoride* solutions, *Copper Sulphate*, etc., and (*v*) mixed impregnation, first with a *salt* and then with a *creosote* oil.

(*i*) POWELLIZING.

In favour of *Powellizing*, we have experiments which have now been in progress for over six years, yielding satisfactory results. It is understood that, in Australia, *Powellizing* has been introduced in recent years, with the object of thoroughly testing its value for preserving Railway sleepers. Taking these facts into consideration, the writer is strongly in favour of following the lead given by the Australian Engineers and of giving this process an extensive trial in India.

(*ii*) COAL-TAR CREOSOTES.

Without doubt, *Coal-tar creosotes* are excellent preservative agents for timber, as they have withstood the test of time and still hold their own against almost all other solutions. Such an assertion requires qualification, in as much as all *Coal-tar creosotes* are not suitable for

treating timber: the suitability or otherwise of the oil is dependent on its composition. Some *creosotes* contain more tar acids than others, while others contain an excess of *crésolic* and *phénolic* substances which, though of a highly antiseptic nature, are too volatile to be used in the treatment of railway sleepers. Thus not more than 8 per cent. of tar acid should be present, while the oil used should commence to boil at about 205°C. and contain a predominance of Napthaline oils, boiling up to 250°C. and the remaining Anthracene oils boiling up to 360°C. and over.

Various specifications have been laid down by Experts, Railway Companies and Timber Treating Associations from time to time, a few of which, together with the analyses of the oils used in the experiments described in the previous chapters, are given below, which may help interested persons in their choice of a suitable oil:—

TABLE XXXVII.

Analysis carried out by Dr. Frank.		By Mr. Puran Singh, Chemical Adviser, Forest Research Institute.			
Name of Antiseptic.	*Green oil.*	*Avenarius Carbolineum*	*Solignum.*	*Liquid Fuel.*	*Avenarius Carbolineum* and *Liquid Fuel* oils mixed in equal proportions.
Specific gravity at 15°C.	1·096	1·130	1·095	at 30°C.—0·848	not recorded.
Water	a trace only	1·40 per cent.	1·10 per cent.	2·65 per cent.	
Solids at 15°C.	*Nil.*	0·92 ,,	0·43 ,,	at 30°C. 0·59 per cent.	
Tar acids	5 per cent.	1·51 ,,	3·35 ,,	0·08 per cent.	
No. of drops coming over at 160°C.	*Nil*	1st drop	*Nil*	*Nil*	*Nil.*
Ditto 180°C.	,,	*Nil*	1st drop	1st drop at 185°C.	,,
Ditto 200°C.	,,	,,	(not recorded)	(not recorded)	,,
Ditto 210°C.	,,	3rd drop	21st drop	12th drop	1st drop.
1st drop at 221°C.					
Ditto 230°C.	3rd drop	7th ,,	62nd ,,	29th ,,	3rd ,,
Ditto 250°C.	11th ,,	17th ,,	143rd ,,	52nd ,,	16th ,,
Ditto 270°C.	30th ,,	21st ,,	218th ,,	109th ,,	40th ,,
Ditto 300°C.	51st ,,	48th ,,	357th ,,	203rd ,,	125th ,,
Ditto 320°C.	63rd ,,	(not recorded)	(not recorded)	(not recorded)	(not recorded)
Ditto 360°C.	88th ,,	Do.	Do.	Do.	Do.

By examining these analyses it will be seen that *Green oil*, which is a commercial *Coal-tar* creosote, fulfills all the conditions necessary for a

good antiseptic solution. It commences to boil at 221°C. and contains oil boiling at over 360°C. and therefore contains no *Phénol* or *Crésol* oils, which is probably an advantage when considering oils for use in the hot climate prevailing in India. *Avenarius Carbolineum* oil contains even higher boiling point oils than *Green oil*, as only 48 drops of the former against 51 drops of the latter, passed over at 300°C. *Green oil*, on the other hand, contains 5 per cent. of acids against 1·51 per cent. in *Avenarius Carbolineum.*

Solignum contains a high percentage of lighter oils, probably of a *Phénolic* and *Crésolic* character and is therefore highly antiseptic. It also contains a fair proportion of heavy oils, for at least half the oil tested remained in the flask after the temperature had been raised to over 300°C.

The *Liquid Fuel* oil shows relatively lower boiling points than *Coal-tar creosotes* which, together with their low toxic value, would probably debar it from being used unmixed with a creosote oil.

The mixture of *Avenarius Carbolineum* and *Liquid Fuel* gives a quite satisfactory analysis, indicating that the mixture may be of great value for treating timber under Indian conditions, especially as it reduces the cost of the solution, thus either permitting greater quantities of the oil being used or, if that is not desired, considerably reducing the cost of treatment.

The analyses given above are for oils used in the experiments carried out and described in Parts III, IV and V ; below are given some standard specifications, fixed for creosote oils used in Europe and America.

The following is the specification for creosote oil fixed by the London North-Western Railway :—

18	per cent. between	205°C. and 245°C.
12	,, ,,	245°C. and 270°C.
22	,, ,,	270°C. and 320°C.
15	,, ,,	320°C. and 420°C.
33	,, residue above	420°C.

Elsewhere in this note reference has been made to 160,000 creosoted *Douglas Fir* sleepers being imported into India from British Columbia. The creosote to be used was to conform to the following specifications :—

(1) Completely liquid at 38°C.

(2) Specific Gravity at 38°C.—1·03.

(3) Only 8 per cent. by volume of tar acids to be soluble in a Caustic Soda solution.

(4) No distillate below 200°C., not over 5 per cent. below 210°C., not over 25 per cent. below 235°C., and the residue above 355°C., if it exceeds 5 per cent. in quantity, should be soft.

The oil actually used had a specific gravity 1·04 at 38°C., 13 per cent. by volume of Tar acids extracted at 38°C., no distillate at 200°C., 1·2 per cent. at 210°C., 11·2 per cent. at 235°C., and a soft residue comprising 22 per cent. of the total volume remaining at 355°C. This specification is the one adopted for grade I oil by the American Railway Engineers Association.

Grade II oil, as specified by the Association, is similar to the above, with the following modifications that 8 per cent. is allowed to come over below 210°C., and not more than 35 per cent. below 235°C.

The United States Department of Agriculture, Forest Service, Circular 112, by Messrs. A. L. Dean and E. Bateman, entitled "The Analysis and grading of creosotes," gives the analysis of an A grade oil, which is well adapted for *Open Tank* treatment, where excessive loss from volatilization is possible during the process. It runs as follows*:—

Percentage of distillate.	*Temperature ranges.*
Nil to 2 per cent. from	200°C. to 230°C.
10 ,, ,,	218°C. to 240°C.
20 ,, ,,	225°C. to 260°C
30 ,, ,,	230°C. to 289°C.
40 ,, ,,	238°C. to 311°C.
50 ,, ,,	257°C. to 326°C.
60 ,, ,,	285°C. to 340°C.
70 ,, ,,	306°C. to 354°C.

The remainder as residue.

The above are the maximum and minimum percentages permissible in A grade oil. Taking an average of these extremes, a high grade creosote oil would be obtained, with boiling fractions, as given below :—

	Per cent.
Distilling at 210°C.	*Nil*
,, ,, 220°C.	5
,, ,, 230°C.	10
,, ,, 240°C.	15
,, ,, 250°C.	23
,, ,, 260°C.	30
,, ,, 270°C.	37
,, ,, 280°C.	43
,, ,, 290°C.	47
,, ,, 300°C.	50
,, ,, 310°C.	55
,, ,, 320°C.	60
,, ,, 360°C.	80

* Note.—These figures are given in diagrammatic form in the above quoted publication

(*iii*) MIXED COAL TAR CREOSOTE AND PETROLEUM PRODUCTS.

We have to consider the possibility of mixing a *Coal-tar creosote* with a cheap *mineral oil,* such as is obtained by rectifying Burma, Assam or Persian earth oils, from which Kerosine oil is prepared. Such oils are very considerably cheaper than *Coal-tar creosotes,* so that in the event of the sleepers which have been treated with mixtures of *Coal-tar creosotes* and *Petroleum* oils proving satisfactory, an important advance will have been made in the solution of the problem of treating railway sleepers in India. The functions of *mineral oils* are to distribute the more toxic oils, to act as a water-proofing agent to the timber and to either reduce the cost of treatment or to allow of more oil being injected into the timber.

(*iv*) SALT SOLUTIONS.

The two salts most commonly used in the impregnation of timber are *Chloride of Zinc* and *Copper Sulphate.* Of these, the former has stood the test of time, being still used in a few impregnating plants in America and, to a still greater extent, on the continent of Europe. Recently, soluble fluorides have attracted a considerable amount of attention in America and Austria, while experiments on a laboratory scale have been carried out with them in India. *Arsenic* is another substance which has been used, being an ingredient both in the *Powell* and *Atlas* processes. The reason for not giving pure salts greater attention in India will be explained in the next paragraph.

(*v*) MIXED IMPREGNATION WITH SALT SOLUTIONS AND COAL-TAR CREOSOTES COMBINED.

The last group of antiseptics contain salt solutions such as *Chloride of Zinc, Sodium Fluoride, Copper Sulphate, Atlas* (a patent arsenic solution) and a variety of others which, as has been stated elsewhere, are not considered suitable for the treatment of timber in localities where moisture is in excess, owing to the liability of the salts to be prematurely leached out of the timber. This brings us at once to mixed impregnation, first with a salt and then with an oil, or to mixing the salt and oil together and to treat the timber simultaneously with both preservatives. As a recommendation for this method of treatment, it has the great advantage that it is cheap as, by treating timber with 10 lbs. per cubic foot of a 2 per cent. solution of *Chloride of Zinc,* the cost does not exceed 2 annas 6 pies per broad gauge sleeper, while the quantity of oil with which it is necessary to treat the sleeper amounts to under half that which would

be necessary were it not first treated with the salt. This method of treatment is solely carried out with the object of reducing the cost and it is in no way claimed for it that it will render the timber more durable than would be the case were it subjected to a more drastic creosote treatment.

(6) Cost of Treatment.

The cost of treating a sleeper with an oil or salt will depend on (*a*) the power of absorption of the timber,(*b*) the amount of antiseptic necessary to protect the timber for a desired period and (*c*) the cost of the antiseptic, handling charges and plant.

(*i*) Absorption.

The degree of penetration of an antispetic depends on the method of treatment, the density of the timber, the arrangement and size of the pores, the percentage of sap-wood to heart-wood, and the percentage of moisture in the timber. Thus greater absorption can generally be obtained in *Pressure* plants than in *Open Tanks*, though the period of immersion is a more important factor than pressure. For instance, better penetration is produced by a long period of immersion at a relatively low pressure than by a short immersion period at high pressure. Again, penetration does not take place laterally to the same extent as it does along the fibre. In conifer woods, the border pits allow of some lateral penetration taking place, especially from the distributing centres formed by dry resin ducts ; in no case, however, do the medullary rays allow of lateral penetration. Large pores are of great use in distributing the antiseptic, a condition that makes it possible to treat dense hard-woods, such as *Terminalia tomentosa.* In the case of straight-grained timbers containing large wood-vessels, such as occur in *Dipterocarpus pilosus* and *D. tuberculatus*, treatment presents no difficulties, due to the inward flow of the antiseptic down the large pores. *Pinus longifolia* timber is equally easy to treat, not on account of the pores, which are absent but to the presence of large resin ducts in the timber. *Spruce* and *Silver Fir*, on the other hand, are refractory to treatment, due to the absence of distributing channels.

Another important factor which governs the amount of absorption, is the percentage of sap-wood to heart-wood in any given sleeper. Not infrequently, sleepers contain some of both, and the former, if dry,

absorbs the antiseptic solution more readily than the latter, resulting in varying depths of impregnation in the timber. This should be avoided, as far as possible, as it may result in an unnecessary amount of the oil or salt entering into one portion of the sleeper and an insufficient saturation of other portions of the fibre. To overcome this difficulty, the United Provinces Authorities divide their sleepers into two classes, namely, (*i*) those containing ⅓rd or more of sap-wood and (*ii*) those containing less than ⅓rd of sap-wood, each class being treated separately.

The other factor governing the absorption of an antiseptic is the percentage of moisture in the timber : this point has already been dealt with under " Seasoning of Timber." In this connection it is interesting to note that green timber absorbs the solution much more slowly than does seasoned timber, while the maximum capacity of absorption of quite green wood is barely half that of seasoned timber.

(*ii*) THE AMOUNT OF ANTISEPTIC NECESSARY TO PRESERVE THE TIMBER.

The quantity of an antiseptic with which it is necessary to impregnate timber, will depend on the use for which the timber is intended. Thus, piles destined for marine work, or telegraph poles to be placed in marshy ground should be treated " to refusal " which, in the case of conifer timber, containing much sap-wood, may amount to 15 lbs. to 20 lbs. per cubic foot. The amount of creosote required for sleeper treatment will vary from 5 lbs. to 10 lbs. per cubic foot, according to the class of timber dealt with. For instance, the *Pinus longifolia* sleepers, which are being treated by the United Provinces Forest Department, are being given 5 lbs. per cubic foot, this being considered enough to protect the sleepers sufficiently long to ensure their being rejected for mechanical defects before the fibre is destroyed by fungus or white-ants. On the other hand, when dealing with the *Dipterocarp* sleepers, the timber of which is much superior to that of *Pinus longifolia*, 7 lbs. to 8 lbs. per cubic foot is advocated ; while *Terminalia tomentosa*, which is again superior for sleeper purposes to the *Dipterocarp* timber, should be treated to refusal.

To obtain the above results, *Open Tanks* can generally be used if the amount of absorption does not exceed 4 lbs. or 5 lbs. per cubic foot, and the number of sleepers to be treated does not exceed 30,000 to 50,000; but, for heavier impregnation or where larger numbers of sleepers are involved, Pressure plants should be employed.

(*iii*) Cost of the Antiseptic, handling charges and plant.

Throughout this enquiry it will be seen that every endeavour has been made to ascertain ways and means of reducing the cost of treatment, because *Coal-tar creosote,* not being at present produced in this country, has to be imported and is therefore expensive. When the enquiry was commenced, the line taken was to reduce the amount of oil employed; and, though the sleepers treated with small quantities of *Avenarius Carbolineum* oil are so far doing well, the solution to the problem probably does not lie in that direction. The other methods which are being tried are either to use a large quantity of a cheap salt of recognized value and to protect it with a coating of *Coal-tar creosote* oil, or to use a mixture of *Coal-tar creosote* and *Petroleum* oil.

A point which has so far not been touched on is the possibility of producing a good, though relatively cheap, *Coal-tar* creosote from Indian coal. Were it possible to do so, India would at once be put on an equal footing with Europe and America as regards the treatment of timber. There can be no doubt that were cheap creosote available, not only would the Railways benefit greatly by being able to procure serviceable sleepers in large quantities, but that the Forest Department would be in a position to utilize many of its so-called "inferior timbers," while a new industry would spring up by the manufacture of *Coal-tar creosotes.* An enterprising Calcutta firm has the business of producing *Coal-tar creosote* under consideration: they have already produced a fair grade of creosote, on which they are now working to bring it up to specification. Considering the question from a general standpoint, there should be no difficulty in profitably producing *Coal-tar creosote* oils in India, in view of the fact that at least three, if not four, large concerns are producing tar in coke ovens. Up to date *Coal-tar* has realized high prices in India, but as the tar market is likely to be flooded on the expansion of the industry, the natural outlet for the surplus tar would be the manufacture of *Coal-tar* creosote.

It is of interest to examine the actual figures arrived at by treating experimental sleepers, as described in the previous chapters. While doing so, it must be remembered that owing to the temporary nature of the work, the labour charges were excessive, while unnecessary expenditure was incurred owing to mistakes or unforeseen difficulties. Nevertheless, an examination of the figures arrived at are instructive as denoting a maximum figure of cost, and therefore, in the event of the cost price falling within working limits, clearly indicating the commercial possibility of such an undertaking.

TABLE XXXVIII.

Estimated cost of treating sleepers based on the experiments described in Chapters III and IV, exclusive of cost of extraction and of Royalty on the timber.

Species.	Locality from whence procured.	*Powellized* sleepers.	*Avenarius Carbolineum*	*Chloride of Zinc* and *Green* oil.	*Solignum* and *Liquid Fuel* oil.	REMARKS.
		Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	
Pinus longifolia.	Chakrata Division, United Provinces.	1 1 0 per B. G. sleeper.	0 12 4 per B. G. sleeper.	1 1 4 per B. G. sleeper.	1 5 0 per B. G. sleeper.	40 per cent. *Solignum* and 60 per cent. *Liquid Fuel* oil.
Pinus excelsa	Ditto	Do.	Do.	Do.		
Dipterocarpus tuberculatus.	Pyinmana Division, Upper Burma.	1 3 0 per B. G. sleeper.	0 7 3 per M. G. sleeper.	0 9 0 per M. G. sleeper.	0 14 10 per M. G. sleeper.	33 per cent. *Solignum* and 67 per cent. *Liquid Fuel* oil.
Dipterocarpus alatus.	Ditto	Do.	Do.	Do.	Do.	Ditto
Terminalia tomentosa.	North Kanara, Bombay; those treated with *Chloride of Zinc* and *Green oil*, from Betul Division, Central Provinces.	1 2 3 per B. G. sleeper.	0 9 5 per M. G. sleeper.	1 0 2 per B. G. sleeper	1 3 8 per B. G. sleeper.	....

From the above table it will be seen that the cost of treating broad gauge sleepers by the *Powell* process varied between Re. 1-1-0 to Re. 1-3-0. The treatment of broad gauge sleepers with *Avenarius Carbolineum*, as carried out in these experiments, was extremely cheap, in spite of the oil costing as much as Re. 1-12-0 per gallon. The cost of treating broad gauge sleepers with *Chloride of Zinc* and *Green oil* varied between Re. 1-0-2 and Re. 1-1-4. This is, in practice, probably the cheapest method of all by which timber can be treated; for, though the figures given in the accompanying table do not substantiate this assertion, the amount of antiseptic introduced into the timber under these experiments was in considerable excess of that in all the other experiments. The cost of treating broad guage sleepers with a mixture of *Solignum* and *Green oil* was relatively high, in spite of the proportion of the more expensive oil being reduced to 33 per cent., the reason being obviously the high cost of *Solignum*. On the other hand, were a good grade of *Creosote* to be substituted for this oil and mixed with a cheap *Petroleum* oil, the cost of treatment could be considerably reduced. This procedure has been adopted in treating the United Provinces 'Chir' sleepers though, in this instance, the amount of oil to be absorbed per sleeper has been raised to 15 lbs., involving a corresponding rise in the cost of treatment. From experience gained in recent years, it is thought that any treatment which involves a maximum cost of more than Re. 1-4-0 to Re. 1-6-0 per

broad gauge sleeper is doubtfully sound, unless either the sleepers can be supplied at the treating plant at an extremely low cost, or the purchasers are willing to pay for the extra amount of oil introduced into the timber.

PART VII.

GENERAL DISCUSSION ON THE TREATMENT OF TIMBER IN INDIA.

(1) The treatment of timber other than sleepers.

Owing to the ravages of white-ants, and to the premature decay of timber in India, when used in construction as posts, telegraph poles, for weirs and bridge work, etc., attempts have, from time to time, been made to protect the timber by artificial means though, in this connection, we are far behind other countries. Enquiries have been repeatedly made by officers of the Public Works Department, by Railway Officials and by private individuals as to the best method of treating timber other than for sleepers, to effectively protect it from the attacks of white-ants or fungi or both. The answers given have necessarily had to be brief, and could not deal with the subject in detail. It is therefore thought that it would not be out of place to conclude this note by giving a short résumé as to how best to deal with such cases.

(*i*) Treatment of constructional timber.

When considering the question of treating constructional timber, the following points have to be borne in mind : (*i*) the quantity and size of the timber which it is desired to treat, (*ii*) the position in which it is to be placed, (*iii*) the choice of antiseptic, and (*iv*) the cost. If the timber to be treated is for a large building, in other words, in considerable quantity, probably the erection of an *Open Tank* in which to treat the timber will be justified. Such a tank can be obtained for Rs. 300 to Rs. 500, according to its capacity, provided it is intended only for temporary work. The tank in which several thousand sleepers were treated at Jagadhri, and at Shahpur in the Central Provinces, cost under Rs. 200. The dimensions of the tank should be dependent on the size of the material to be treated. The tank should be sunk into the ground to within 6″ of the top, and if the oil is to be heated by direct fire and not by a steam coil, a 'Kutcha' masonry flue should be constructed underneath and along the length of the tank, with a sloping entrance at one end and a

short chimney at the other. It may be found convenient to erect a tripod over the tank, to which should be attached a set of pullies to facilitate the loading and unloading of the timber. On the tank being charged, the antiseptic solution should be heated to between 80°C. and 90°C. and then allowed to cool down. The time, during which the timber is allowed to remain in the solution, will depend on the amount of antiseptic it is proposed to introduce into the timber, the nature of the timber and the size of the pieces to be treated. It is not improbable that some of the timber to be treated will be found to be too long to go into the tank, such as beams and possibly some of the posts; for, to build a tank of sufficient size to take such timber would not be justified owing to the limited number of such pieces to be treated. Such timber can, however. be given a considerable amount of protection by placing it over the tank and ladling the hot solution over it for 10 or 15 minutes and by repeating this operation at least twice.

It has been mentioned that the position in which the timber is to be placed would affect the method of treatment to be adopted. In the case of timber which is destined for indoor work, the amount of protection which it is necessary to give is less than in cases when it will be exposed to atmospheric influences. Thus, in the case of Pine rafters for roofing, 2 lbs. or 3 lbs. per cubic foot might be sufficient, while 5 to 6 lbs. per cubic foot of the antiseptic would be necessary to effectively protect verandah posts. Wood coming in contact with the ground, on the other hand, should be treated to refusal in *Open Tanks*.

The choice of antiseptic, with which to treat timber destined for constructional work in dwelling houses, is a somewhat difficult problem. *Creosotes*, as used for sleeper work, cannot be used for internal work, as their odour is offensive, another reason being that creosoted wood cannot be painted. Good results have been obtained with *Solignum*. When first applied, it smells of creosote but this soon passes off. *Arsenic solutions*, such as *Atlas*, have been extensively used, especially in Assam, and the results obtained with this antiseptic are claimed to be quite satisfactory, the only objection to it being the poisonous nature of the solution. A very useful salt, with which to treat timber destined for internal construction, is *Chloride of Zinc*, used in a 2 per cent. solution; it is cheap, colourless and odourless and provided the timber is well saturated, affords considerable protection. The timber, after treatment, on being thoroughly dried, should be painted with any suitable pigment mixed with oil. The above remarks are based on the assumption that the timber is destined for internal work in dwelling houses; in the case of store-houses, barns, wooden bridges, canal weirs and structures of a similar nature, *creosote* alone or mixed with *Petroleum* oils is advocated, as the

objectionable smell of the *creosote* is, in such cases, generally of little or no consequence. The cost of treatment will depend on the depth of impregnation desired and the choice of antiseptic. *Creosote* and *Petroleum* oils, mixed in equal quantities, cost about 9 pies per lb.; *creosote* alone, which has to be imported from Europe, costs about 14 pies per lb. landed at Delhi or any other town in Northern India. *Solignum* costs Rs. 15 to Rs. 18 per 5-gallon drum, according to colour ; *Jodelite* costs Rs. 2-11-0 per gallon ; *Atlas* ' A ' solution concentrated Rs. 16 in 5-gallon drums ; *Green oil*, imported from England, comes to about 13 annas per gallon at Delhi ; while *Chloride of Zinc* costs Rs. 20 per cwt. in Calcutta. The above are pre-war rates. From the above it will be seen that the patent solutions such as *Solignum* and *Jodelite* are expensive, but their nature allows them to be used for internal purposes in dwelling houses, which is not the case with the cheaper *creosote* oils of commerce. The salts are very cheap and may be considered fair preservatives, but as the timber after treatment probably requires to be painted, the total cost is considerably enhanced.

The above considerations have been based on the assumption that it has been decided to treat the timber by the *Open Tank* process but, if the amount of timber is insufficient to justify the erection of an *Open Tank* in which to treat it, the only alternative is to treat the timber by applying one or more coatings of the preservative in a hot state with a brush.

No mention has been made above of *Powellized* timber, as to erect a *Powell* plant to treat small quantities of timber only is probably out of the question. On the other hand, *Powellized* timber is very suitable for use in dwelling houses, as the treatment in no way adversely alters the appearance of the timber ; moreover, such timber gives off no offensive odour and permits of being painted after treatment.

(*ii*) Treatment of Posts, Fencing poles, Telegraph poles and mining props.

It is a well-known fact that posts and poles of all descriptions, unless of the most durable timber, are especially liable to decay. The decay is most rapid in cases where the timber is placed in contact with the ground and in cases where sap-wood is present. Fencing and telegraph posts show the first signs of decay just above and below ground ; in fact, unless a post is in an advanced stage of decay, the damage is generally confined to a 3 feet zone partly above and partly below ground. The bottoms of posts are often found to be quite sound, while the middle portion may have nearly disappeared. This is due to want of light

and air at the bottom of the post, conditions unfavourable to the action of fungoid growth. It necessarily follows that the greatest measure of protection must be given to the most vulnerable portions of the timber. In the case of fencing posts, which are generally not buried deep in the ground, it is not usually economically sound to differentiate between the lower and middle zones and, therefore, to facilitate matters, it is customary to treat the whole of the lower end of the post. In the case, however, of telegraph poles, which have to be buried deep in the ground, and especially when large numbers have to be treated and economy is a consideration, only about 2 feet above and below ground are treated. These remarks apply to cases in which the poles only contain heart-wood ; if, on the other hand, sap-wood is present the whole of the post should be treated, special attention being paid to the lower end.

In cases of mining props destined for erection in main galleries, in other words when the supports are of a more or less permanent nature, the posts should be treated throughout their length to refusal either in *Open Tanks* or preferably under pressure. The same remarks apply to timber to be placed in water, in such situations for instance, as weirs or sluice gates, which are subjected to the alternate action of water and a process of drying.

In the event of there being sufficient timber to justify the erection of an *Open Tank*, in which to treat the posts or telegraph poles, the best type of tank in which to treat the butts is a circular tank of from 6 feet to 8 feet diameter and of sufficient height to enable the ends of the post to be submerged in the antiseptic to the required depth.

Before leaving this subject, it should be mentioned that when considering the treatment of the ends of posts only, it is not intended to convey the idea that it is not better to treat the timber throughout : the idea of partial impregnation is only advocated from the point of view of economy. Moreover, it should be clearly understood that treatment under pressure is preferable to *Open Tank* treatment and that this treatment is again preferable to the *Brush* method of treatment, the selection of the process to be adopted depending on the quantity and quality of the timber to be dealt with and the purpose for which it is destined.

(2) General discussion.

It must be admitted that India is far behind most other civilized countries in the matter of treating timber and this may be attributed to the large supplies of timbers exceptionally durable in their natural state. These supplies are falling short of the ever-increasing demand,

especially in connection with sleeper woods, not that the present outturn of such timber has decreased, but that demand has forced up the prices to a point at which it is no longer profitable to convert more than a limited amount of such timbers into sleepers. The result is a shortage of sleeper woods and a corresponding tendency to look elsewhere for further supplies. This demand can, no doubt, be partially met by importing sleepers but, without a doubt, also by treating indigenous species of Indian timbers.

The Indian timbers which, it is thought, might prove suitable for sleepers, after treatment, are given in Chapter VI, Section 2. They are available from different provinces of India, the largest supplies being probably of *Dipterocarpus turbinatus* and *Terminalia Manii* from the Andamans; *Terminalia myriocarpa* and *Dipterocarpus pilosus* from Assam; *Dipterocarpus tuberculatus*, *D. alatus* and *Terminalia tomentosa* from Burma; *Abies Pindrow* and *Picea Morinda* from the Punjab and Kashmir; *Pinus longifolia* from the United Provinces and Punjab; and *Terminalia tomentosa* and *T. paniculata* from the West Coast of India. Without doubt, many other suitable species exist and localities could be named from which they, or the above timbers, could be obtained in considerable quantities, but the above list and localities may be considered as amongst the most important in British India.

The above remarks apply only to sleeper woods, but the treatment of constructional timber also deserves careful consideration. As far as the writer knows, with few exceptions, the Public Works Department, Canal Engineers, Railway Engineers, Builders and Private persons confine their efforts to protect constructional timber simply by painting, or varnishing the timber they employ in their works. This may or may not be sound business, it depends on the natural durability of the timber employed and the cost of replacing it at stated intervals. It is certain, however, that were treatment of timber more universally adopted for such purposes as we are considering, many Indian timbers at present not used for construction could be employed with equally good results, and at a cheaper initial cost, provided they were properly seasoned and treated before use. Moreover, the ever-increasing prices which it is necessary to pay for first class timber, and the shortage of supplies in some localities all point to the importance of giving careful consideration to this proposition which, if adopted, can but have the result of husbanding the timber resources of this country.

APPENDIX I.

List of publications and reports on the Antiseptic Treatment of Timber.

1. *English publications.*

1. Creosoted Wooden Poles.—*Timber Trades Journal,* 1907, Vol. LXII, page 570.

2. The Antiseptic Treatment of Timber,—by Sir Samuel Bagster Boulton, Bart. (Waterlow Bro. and Layton, Ltd., 24 and 25, Birchin Lane, E.C.)

3. Wood Preservation.—Paper read before the Central Electric Railway Association, by A. L. Kuehn, and reproduced in the *Timber Trades Journal,* August 5th, 1911, page 177.

4. The *Rueping Process* of Creosoting.— *Timber Trades Journal,* September 9th, 1911.

5. The Antiseptic Effect of *Creosote oil* and other oils used for preserving timber,—by John M. Wiess. (*Journal of the Society of Commercial Industry,* December 15th, 1911.)

2. *Indian publications.*

1. Memorandum on the establishment of a factory for impregnating Pine sleepers from the North-West Himalayas with metallic salts, by Dr. H. Warth, September 1878.

2. Memorandum on the supply of railway sleepers of the Himalayan Pines suitable for impregnation in India,—by Sir D. Brandis (*Inspector-General of Forests' Proceedings,* October 1878).

3. Impregnation of Himalayan Pine-wood for use as Railway sleepers.—*Government of India, Department of Revenue, Forests.—Proceedings* Nos. 8 to 10, May 1879.

4. Preservation of Timber.—*Indian Forester,* 1881, Vol. VI, page 142.

5. The Antiseptic Treatment of Timber.—*Indian Forester,* 1884, Vol. X, page 582.

6. The Preservation of Timber.—*Indian Forester,* 1886, Vol. XII, pages 127-137.

7. Methods of Preserving Timber in Japan.—*Indian Forester,* 1886, Vol. XII, page 527.

8. Preservation of Timber with *Carbolineum* oils.—*Indian Forester,* 1888, Vol. XIV, page 285.

9. Gardner's Process of Preserving Timber.—*Indian Forester,* 1889, Vol. XV, page 479.

10. Creosoting sleepers.—*Indian Forester,* 1891, Vol. XVII, page 217.

11. Creosoting timber.—*Indian Forester,* 1892, Vol. XVIII, page 238.

12. Pfister's process.—*Indian Forester,* 1892, Vol. XVIII, page 277.

13. Haskin's process.—*Indian Forester,* 1896, Vol. XXII, pages 32 and 33.

14. Haskin's process.—*Indian Forester,* 1898, Vol. XXIV, page 224.

2. Indian publications—contd.

15. Impregnation of Indian Timbers.—*Proceedings* Nos. 1 to 7, *of the Inspector-General of Forests*, July 1898.

16. Impregnation of Indian Timbers.—*Indian Forester*, 1898, Vol. XXIV, page 345.

17. Hasselmann's process.—*Indian Forester*, 1898, Vol. XXIV, page 439.

18. Report on Haskin's process.—*Indian Forester*, 1899, Vol. XXV, Appendix.

19. Preservation of timber by impregnation or the Haskin process.—*Proceedings* No. 8 *of the Inspector-General of Forests*, 1902.

20. Opinions of Local Governments and Railway Administrations on the proposal for establishing a central factory for the purpose of impregnating sleepers of inferior wood, or treating them by the Haskin's process.—*Public Works Department, Railway Stores*, IX. *Proceedings* of June 1902, Nos. 91—126.

21. Preservation of Bamboos from the attacks of the Bamboo beetle or "shot-borer."—by E. P. Stebbing, F.L.S., Calcutta, 1903.

22. Powell's process.—*Indian Forester*, 1903, Vol. XXIX, page 580.

23. Report of the Sub-Committee of the Board of Scientific Advice on Indian Timber sleepers.—"A" *Proceedings* Nos. 17-20 *of the Inspector-General of Forests*, 1905 (containing Mr. F. D. Couchman's note on the necessary quality of good railway sleepers).

24. Powell's process.—*Indian Forester*, 1906, Vol. XXXII, page 618.

25. Powell's process.—*Indian Forester*, 1907, Vol. XXXIII, page 281.

26. Powell's wood process for treating newly felled timber.—"A" *Proceedings* Nos. 66-67 *of the Inspector-General of Forests*, March 1907.

27. Utilization of Railway sleepers of inferior kinds of timber.—"A" *Proceedings* Nos. 5-7 *of the Inspector-General of Forests*, April 1907.

28. Utilization of inferior kinds of timber for railway sleepers.—*Proceedings of the Railway Board* (R. S.), September, 1907.

29. Powell's wood process for preserving timber.—*Railway Department, Proceedings* Nos. 156-165, June 1909.

30. Note on the Antiseptic Treatment of Timber in India, with special reference to Railway sleepers,—by R. S. Pearson, I.F.S., F.L.S. (*Indian Forest Records*, Vol. III, Part II, March 1912).

31. Sleeper Treatment. (*Indian Engineering*, July 13th. 1912, page 24.)

32. Factors in Wood Preservation. (*Indian Engineering*, April 12th, 1913.)

3. American publications.

1. The Decay of Timber and Methods of Preventing it.—*Bureau of Plant Industry, Bulletin* 14, 1902.

2. Seasoning of Timber.—*Forest Service Bulletin* 41, 25 cents., 1903.

3. Cross Tie Forms and Rail Fastenings with Special Reference to Treated Timbers.—*Bulletin* 50, 15 cents., 1904.

4. Report on Condition of Treated Timbers Laid in Texas, February, 1902.—*Bulletin* 51, 10 cents., 1904.

5. Wood Preservation in the United States.—*Bulletin* 73, 10 cents., 1909.

6. The Preservative Treatment of Farm Timbers.—*Farmers' Bulletin* 387. 1910.

7. The Fractional Distillation of *Coal-Tar Creosote.*—*Forest Service Circular* 80. 1907.

3. American publications—contd.

8. Quantity and Character of Creosote in Well Preserved Timbers.—*Forest Service Circular* 98, 5 cents., 1907.

9. The Open Tank Method for the Treatment of Timber.—*Forest Service Circular* 101. 1907.

10. Brush and Tank Pole Treatments.—*Forest Service Circular* 104. 1907.

11 The Analysis and Grading of Creosotes.—*Forest Service Circular* 112. 1908.

12. The Preservative Treatment of Fence Posts.—*Forest Service Circular* 117. 1907.

13. Preservation of Piling Against Marine Wood Borers.—*Forest Service Circular* 128, 5 cents., 1908.

14. Experiments on the Strength of Treated Timber. (Second Edition.)—*Forest Service Circular* 39, 5 cents., 1908.

15. Holding Force of Railroad Spikes in Wooden Ties.—*Forest Service Circular* 46, 5 cents., 1906.

16. Wood Paving in the United States.—*Forest Service Circular* 141. 1908.

17. The Seasoning and Preservative Treatment of Hemlock and Tamarack Cross Ties.—*Forest Service Circular* 132, 5 cents., 1908.

18. The Estimation of Moisture in Creosoted Wood.—*Forest Service Circular* 134, 5 cents., 1908.

19. Primer of Wood Preservation.—*Forest Service Circular* 139. 1908.

20. Experiments with Railway Cross Ties.—*Forest Service Circular* 148, 5 cents., 1908.

21. Consumption of Wood Preservatives and Quantity of Wood Treated in 1910.—*Forest Service Circular* 186, 5 cents., 1911.

22. Preservative Treatment of Loblolly Pine Cross Arms.—*Forest Service Circular* 131, 5 cents., 1908.

23. Preservative Treatment of Poles.—*Forest Service Bulletin* 84, 15 cents., 1911.

24. Volatilization of Various Fractions of Creosote after their Injection into Wood.—*Forest Service Circular* 188, 5 cents., 1911.

25. Modification of Sulphonation Test for Creosote.—*Forest Service Circular* 191, 5 cents., 1911.

26. Prevention of Sap Satin in Lumber.—*Forest Service Circular* 192, 5 cents., 1912.

27. Progress Report on Wood Paving Experiments in Minneapolis.—*Forest Service Circular* 194, 5 cents., 1912.

28. Quantity and Quality of Creosote found in Two Treated Piles after Long Service.—*Forest Service Circular* 199, 1912.

29. The Preservation of Mine Timbers.—*Forest Service Bulletin* 107, 10 cents., 1912.

30. Commercial Creosotes.—*Forest Service Circular* 206, 10 cents., 1912.

31. The Absorption of Creosote by the Cell Walls of Wood.—*Forest Service Circular* 200, 5 cents., 1912.

32. Condition of Experimental Chestnut Poles in the Warren-Buffalo and Poughkeepsie-Newton Square Lines after Five and Eight years' Service.—*Forest Service Circular* 198, 5 cents., 1912.

33. Prolonging the life of Cross-Ties.—*Forest Service Circular* 118, 15 cents., 1913.

3. American publications—contd.

34. Service Tests of Ties.—*Forest Service Circular* 209, 5 cents., 1912.

35. Experiments in the Preservative Treatment of Red Oak and Hard Maple Cross Ties.—*Forest Service Bulletin* 126, 20 cents., 1913.

36. Relative Resistance of Various Conifers to Injection with Creosote.—*Department of Agriculture Bulletin* 101, 15 cents., 1914.

37. Tests of Wood Preservatives.—*Department of Agriculture Bulletin* 145, 10 cents., 1915.

38. The Toxicity to Fungi of Various Oils and Salts.—*Department of Agriculture Bulletin* 227, 10 cents., 1915.

39. The Preservation of Structural Timbers from Decay—by C. P. Winslow. (*Proc. Eng. Society of Eastern Pa.* Vol. 26, No. 9, pages 427—451, December 1910.)

40. Timber Preservation—by C. P. Winslow. (*Electric Traction Weekly*, 1911.)

41. Structure of Commercial Woods in Relation to the Injection of Preservatives,—by H. F. Weiss. (*Proc.* 8th *International Congress of Applied Chem.* Also *Jour. Ind. and Eng. Chem.* Vol. 5, No. 5. 1912 and May 1913.)

42. Some Tests to Determine the effect upon Absorption and Penetration of mixing Tar with Creosote,—by F. M. Bond. (*Proc. American Wood Preservers Association*, pages 216—274, 1913.)

43. The Transmission of Air Pressure in Cross-Ties,—by C. P. Winslow, (*Proc. American Wood Preservers Association*, pages 288—316. 1913.)

44. A Comparison of *Zinc Chloride* with *Coal-Tar Creosote* for Preserving Cross-Ties,—by H. F. Weiss. (*Proc. American Wood Preservers Association*, pages 71—83. 1913.)

45. Condition of Experimental Poles in the Augusta-Savannah and Helna-Meldrim Lines,—by C. H. Teesdale. (*Engineering News*, November 27th, 1913.)

46. Method of Determining the Amount of $ZnCl_2$ in Treated Wood,—by E. Bateman. (*Jour. Ind. and Eng. Chemistry*, January 1914).

47. The Effect of varying the Preliminary Air Pressure in treating Ties upon the Absorption and Penetration of Creosote,—by C. H. Teesdale. (*Proc. American Wood Preservers Association*, pages 323 to 351, 1914.)

48. Preliminary Work in Fire Proofing Wood,—by R. E. Prince. (*Proc. American Wood Preservers Assn.*, pages 158—172, 1914).

49. Air Seasoning of Timber,—by W. H. Kempfer. (Am. Ry. Eng. Assn. Bulletin 161, *Proceedings Railway Review*, part 2, pp. 163—232, November 1913-14 and 10th January 1914.)

50. Toxicity of various Wood Preservatives,—by C. J. Humphrey and R. M. Fleming. (*Jour. Ind. and Eng. Chemistry*, February 1914.)

51. The Protection of Ties from Mechanical Destruction,—by H. F. Weiss. (*Proc. American Wood Preservers Association*, pages 249—260, *Hardwood Record*, 1914.)

52. Experiments on the Bleeding and Swelling of Southern Yellow Pine Paving Blocks,—by C. H. Teesdale. (*Proc. American Society of Municipal Improvements*—pages 267—286, February 10-14, 1914.)

53. Efficiency of various Parts of *Coal Tar Creosote* against Marine Borers,—by C. H. Teesdale. (*Engineering Record*, 12th September 1914.)

54. How the Wood Preserving Industry can avoid possible injury resulting from the War,—By C. H. Teesdale. (*Engineering Record*, September 26-14, *Mfgrs. Record*, September 24-14. *So. Lumberman* Sept. 26-14, *Ry. Age. Gazette*, October 21-14.)

55. Decay in Wooden Bleachers,—by C. H. Teesdale. (*Engineering Record*, October 3-14, *American Lumberman*, October 3-14.)

3. American publications—concld.

56. Marine Wood Borers,—By C. H. Teesdale. (*Scientific American*, Supplement, December 5-14.)

57. Fire Proofing Wooden Shingles,—By H. F. Weiss. (*American Roofer*, December 1914.)

58. Records on the Life of Treated Timber in the United States,—By H. F. Weiss and C. H. Teesdale. (*Proc. American Wood Preservers Association*, pages 501—509, 1915.)

59. Bleeding and Swelling of Paving Blocks,—By C. H. Teesdale. (*Proc. American Wood Preservers Association*, pages 372—397, 1915.)

60. History of Treated Wood Block Pavements in the United States,—By C. H. Teesdale. (*Proc. American Wood Preservers Assn.*, pages 324—367, 1915.)

61. Temperature changes in Wood under treatment,—By G. M. Hunt. (*Proc. American Wood Preservers Assn.*, pages 85—100, 1915.)

62. Preservative Treatment of Timber,—By H. F. Weiss and C. H. Teesdale. (*International Engineering Congress*, 1915.)

63. The Preservation of Wood from Decay,—By C. H. Teesdale. (*The Armour Engineer*, March 1915.)

64. The Preservative Treatment of Wooden Silos,—By G. M. Hunt. (*American Lumberman*, 13th March 1915.)

65. Service Tests of Treated and Untreated Telephone Poles,—by C. H. Teesdale. (*Telephony*, 3rd April 1915.)

66. Experiments with Wood Paving Blocks (In Minneapolis),—by C. H. Teesdale. (*Municipal Journal*, 6th May 1915.)

67. Tests on the Inflammability of Untreated Wood and of Wood Treated with Fire Retarding Compounds,—By R. E. Prince. (*Proc. National Fire Protection Assn.*, pages 108—157, 1915.)

68. Rot in Stored Lumber,—By C. J. Humphrey. (*American Lumberman*, pages 32—33, 14th August 1915.)

69. Sterilization and Preservation of Line Poles by electricity. (*Forestry and Irrigation*: December 1907, Vol. XIII, page 651.)

70. Increasing the durability of Fence Posts, by F. W. Besley, State Forester, Maryland State, Board of Forestry, Baltimore, Md. 1912.

71. A Silicious Wood Preservative. (*Scientific American*, dated 3rd May 1913, Vol. CVIII, No. 18, page 401.)

72. The Preservation of Structural Timber,—By H. F. Weiss, Director, Forest Products Laboratory, U. S. Forest Service, 1915.

73. Some Factors Affecting the Application of Wood Preservation to Electric Railways,—By C. P. Winlow and C. H. Teesdale. (*Proc. American Electric Ry. Engineering Association*, 1915.)

74. Creosoted *Douglas Fir* Paving Blocks.—(*Association of Creosoting Companies of the Pacific Coast, Seattle, Washington*, October 1915.)

75. Creosoting *Douglas Fir* Bridge Stringers and Ties without Loss in Strength. (*Association of Creosoting Companies of Pacific Coast, Seattle, Washington*, February 1916.)

76. Wood Preserving, Vol. II, No. 4, October-December 1915.

4. French publications.

1. La Préservation des Bois contre la pourriture,—by Professor Henry, of the National Forest School, Nancy, France, 1909.

4. French publications—contd.

2. Éssai en Grand du Carbolineum Avenarius,—by Professor Henry, of the National Forest School, Nancy, France. (*Revue des Eaux et Forest,* No. 7, 1st April 1909.)

3. Préservation des Bois par des Procédés Simples,—by Professor E. Henry, Deputy Director, National Forest School, Nancy, France.

5. Australian publications.

1. Letters on the Powell Process from the Chief Engineer, West Australian Railways. (Antiseptic Ledger File of the Forest Economist, 1909-10.)

6. Austrian publications.

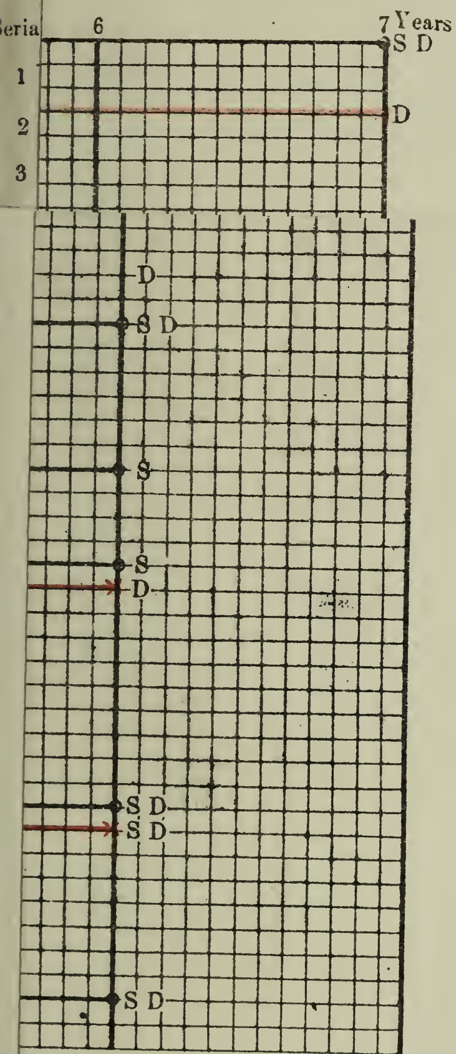
1. Letter on the Antiseptic Treatment of Timber,—by Hauptmann Basilieus Malenkovic of the Austrian Royal Engineers. (Antiseptic Ledger File of the Forest Economist, 1909-10.)

2. Letter on the subject of impregnation with *Fluoride* salts,—by Hauptmann Basilieus Malenkovic of the Austrian Royal Engineers. (Antiseptic Ledger File of the Forest Economist.)

3. Zur Holzkonservierung mit *Fluoriden,*—by Oberbaurat Robert, Nowotny, Vienna.

4. Uber Grübenholz Impragnierung mit 'Bellit,'—by Basilius Malenkovic, K. U. K., Hauptmann.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.



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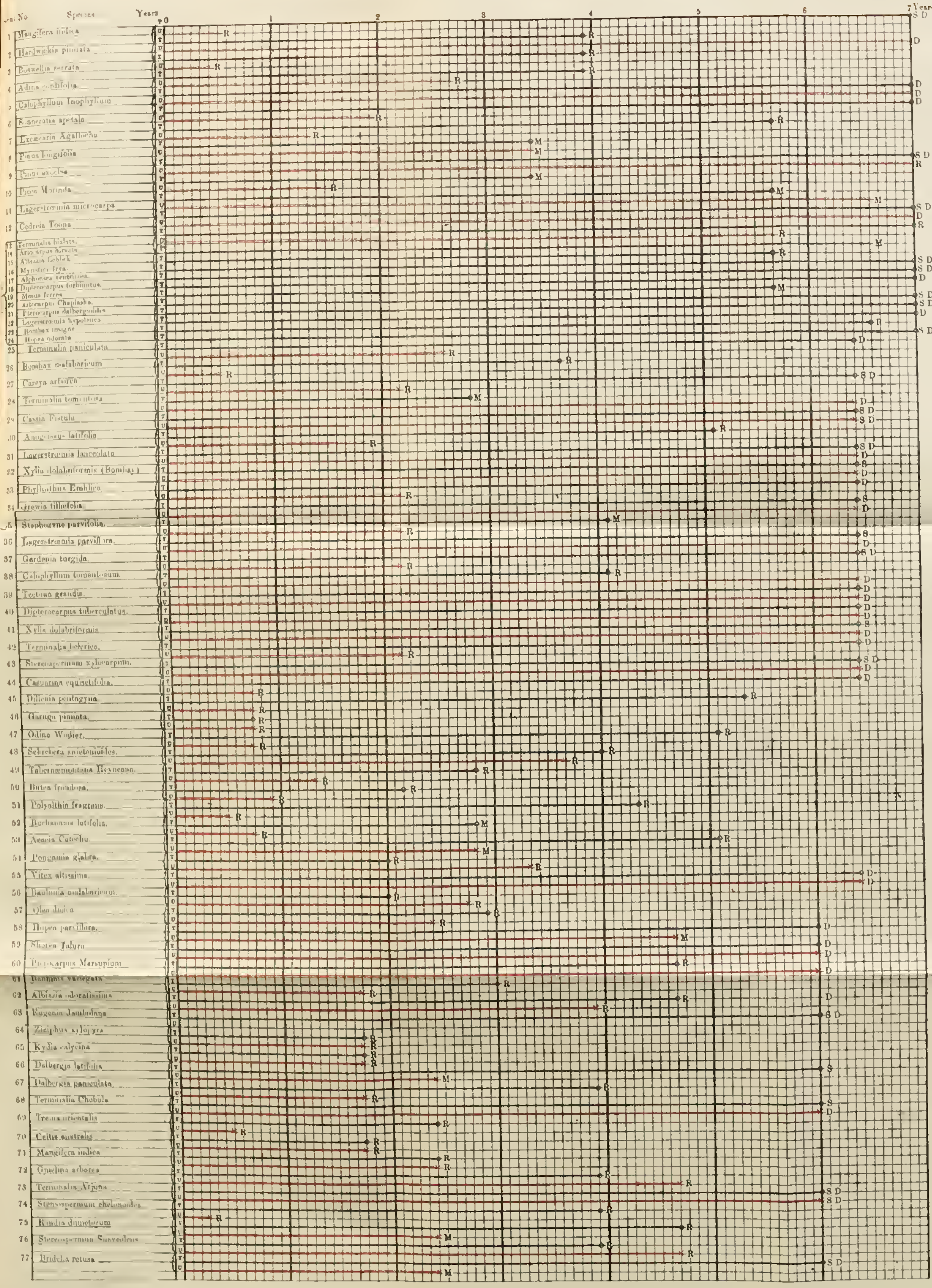
R. S. PEARSON,
Forest Economist.

June, 1917.—No. 147.

DIAGRAM I.

DURABILITY RECORD OF POWELLIZED SPECIMENS.

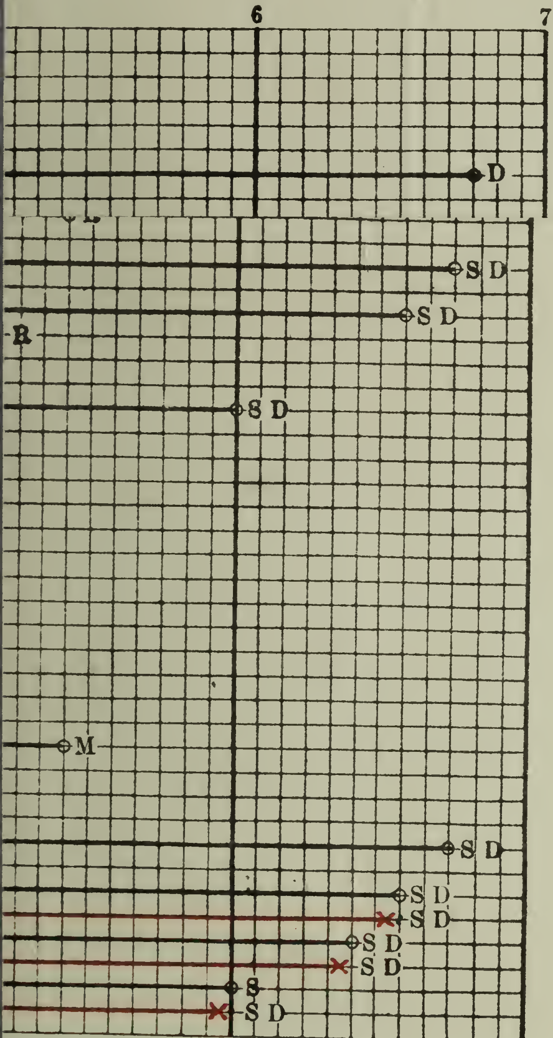


Black Lines denote Treated Specimens "T"
Red " " Untreated " "U"
"S" denotes sound
"SD" " slightly damaged
"D" " damaged but still serviceable
"R" " Rejected and unserviceable
"M" " Missing or Lost

R. S. PEARSON,
Forest Economist

Photo.-Mechl. and Litho. Dept., Thomason College, Roorkee.

M,



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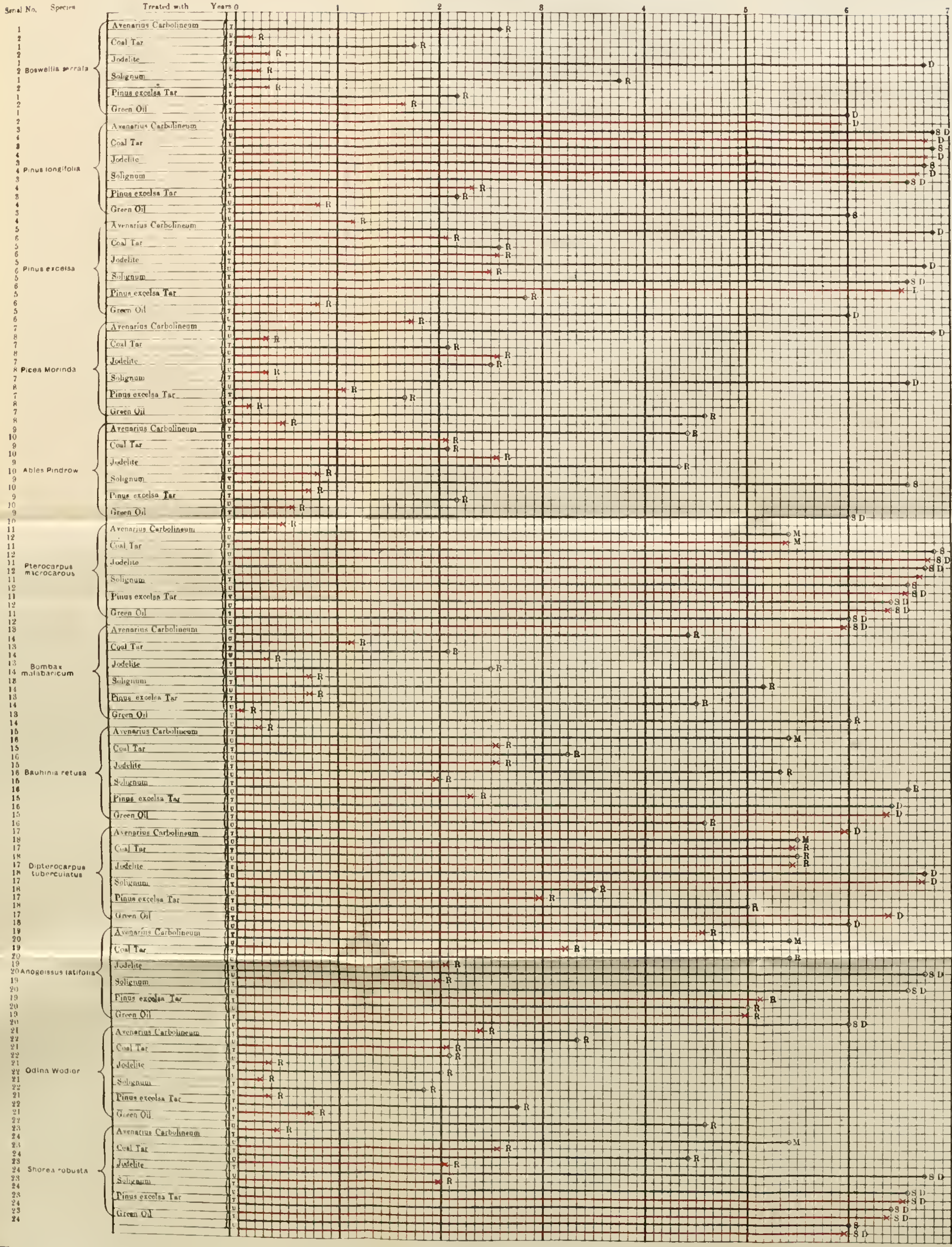
June, 1917.—No. 147-I.-500

DIAGRAM II.

DURABILITY TESTS OF SPECIMENS TREATED WITH AVENARIUS CARBOLINEUM, COAL TAR, JODELITE, SOLIGNUM, PINUS EXCELSA TAR, AND GREEN OIL.



Black Lines denote Treated Specimens "T"
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"S" denotes sound
"SD" " slightly damaged
"D" " damaged but still serviceable
"R" " rejected and unserviceable
"M" " missing

R. S. PEARSON,
Forest Economist.

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June, 1917.—No. 1474-569

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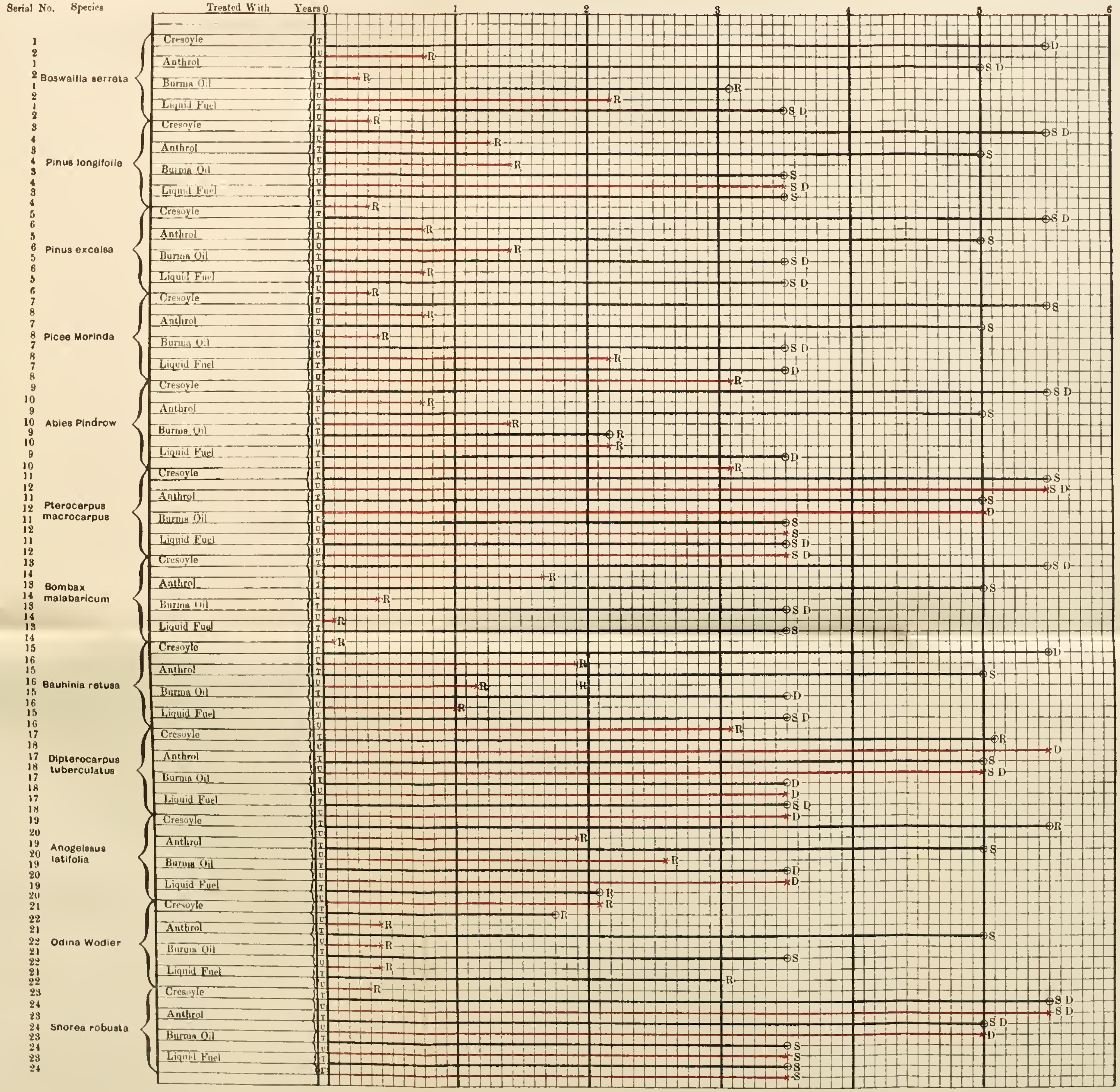
DIAGRAM III.

DURABILITY TESTS OF SPECIMENS TREATED WITH CRESOYLE, ANTHROL, BURMA OIL, AND LIQUID FUEL FROM BORNEO.



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Forest Economist.

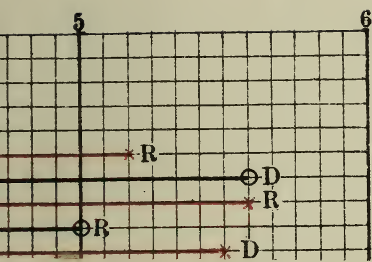

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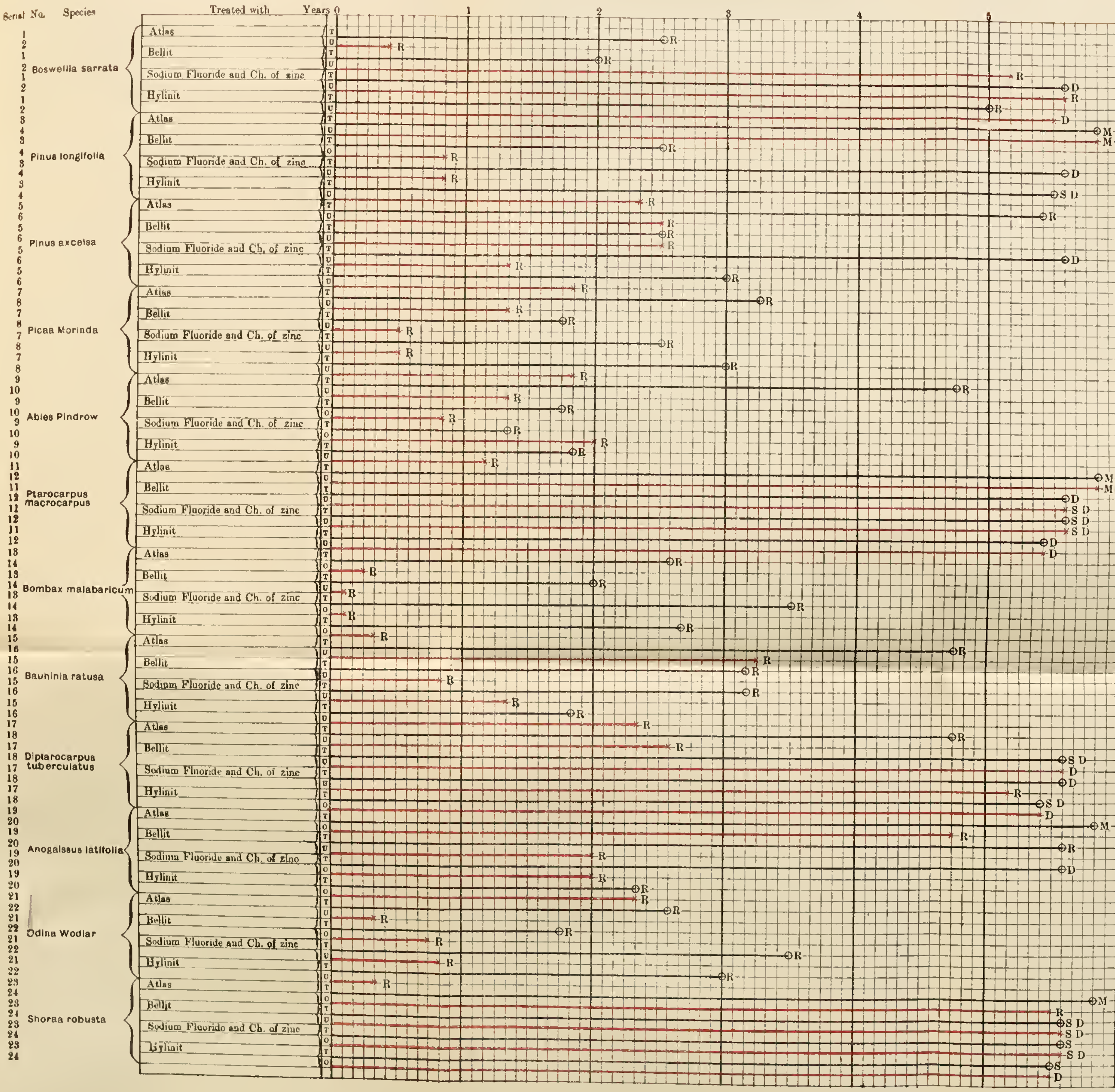
DIAGRAM IV.

DURABILITY TESTS OF SPECIMENS TREATED WITH ATLAS, BELLIT, SODIUM FLUORIDE AND CHLORIDE OF ZINC, AND HYLINIT.



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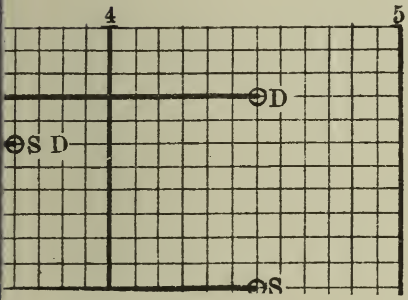
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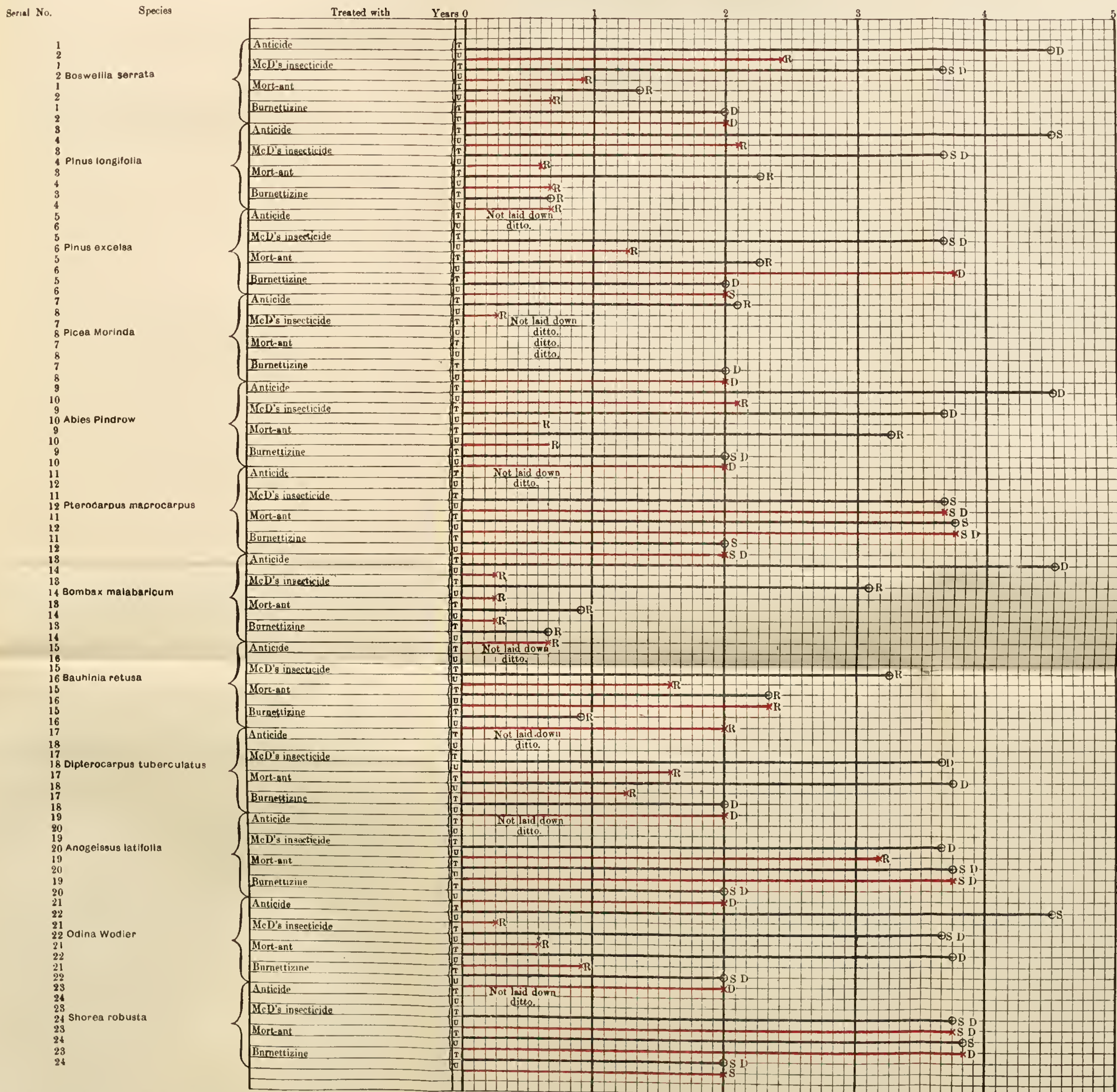
DIAGRAM V.

DURABILITY TESTS OF SPECIMENS TREATED WITH ANTICIDE, McDOUGALLS INSECTICIDE, MORT-ANT AND BURNETTIZINE.



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"M" „ missing

R. S. PEARSON,
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June, 1917.—No. 147-4 1500

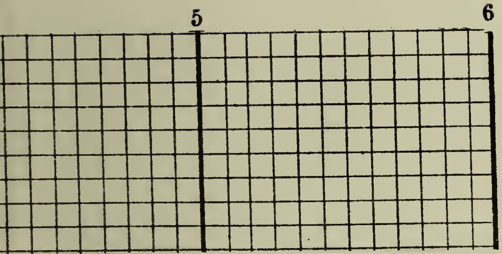
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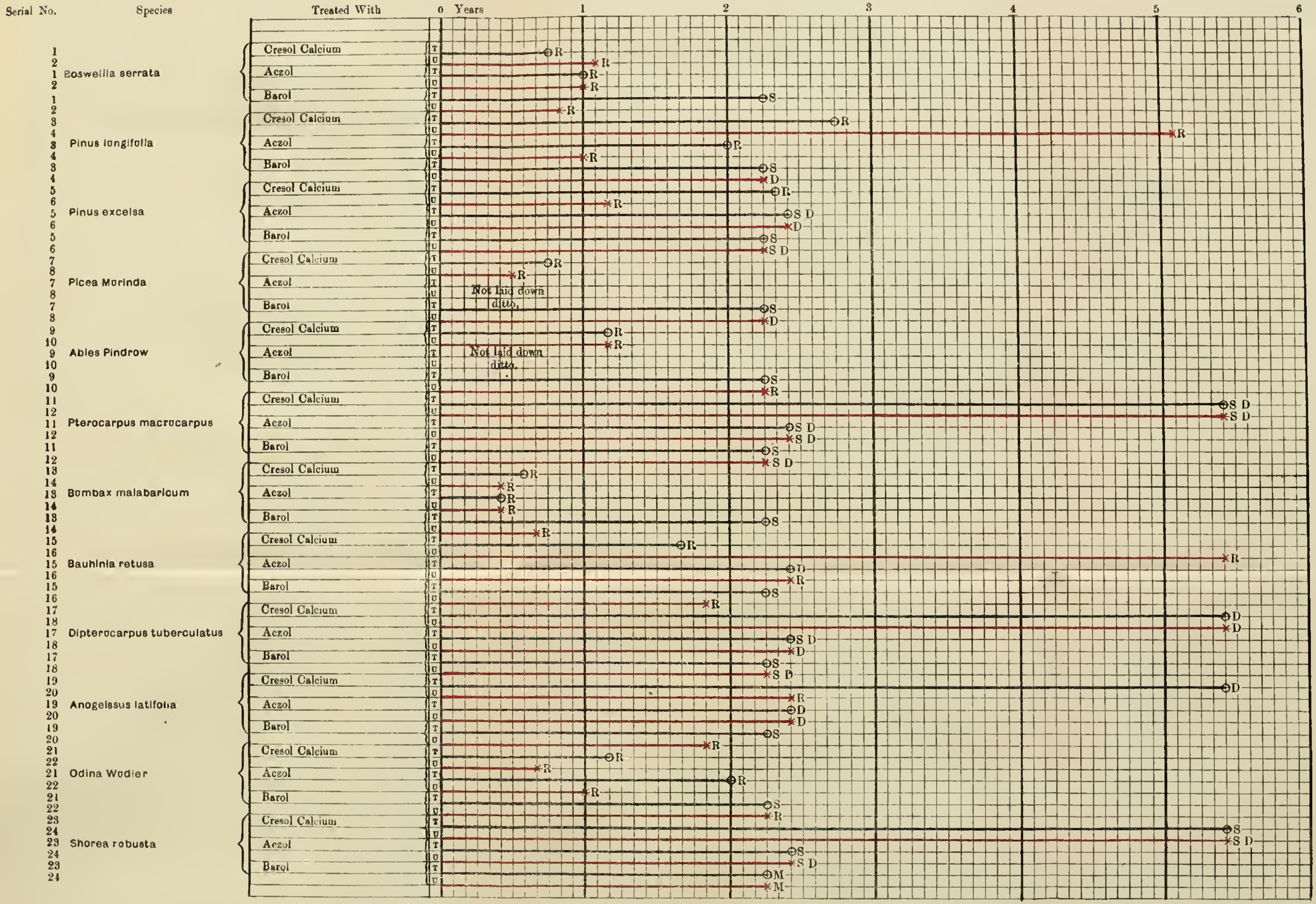
DIAGRAM VI.

DURABILITY TESTS OF SPECIMENS TREATED WITH CRESOL-CALCIUM, ACZOL, AND BAROL.



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"D" " damaged but still serviceable
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"M" " missing or lost

R. S. PEARSON,
Forest Economist.

No. 147-5-1500.

INDIAN FOREST RECORDS

Vol. VI.] 1918 [Part V.

STATISTICS

Compiled in the Office of the Silviculturist, Forest Research Institute, Dehra Dun, during 1916-17.

INTRODUCTION.

It is desirable again to point out that the figures given for girth increments do not represent the rate of growth in even-aged crops. They attempt to indicate the development under existing conditions, that is in untended and irregular forests, where the early life of the trees is spent necessarily in a semi-suppressed state. Only the figures from combined sample plots should be used for reference ; the figures for the individual sample plots are given for comparison one with another. Some misapprehension has been caused by the application of the figures to what may be expected from even-aged and tended crops. This is not the object of publication, which is rather to indicate the need for alteration in treatment when the growth appears unreasonably slow. Insufficient data have been collected as yet to estimate the girth increment of most Indian trees when grown in regular crops. For *Sal* however, the remeasurement of the Forest Research Institute sample plots has afforded an opportunity, and a note on the subject will be published shortly. The Silviculturist wishes to express his indebtedness to the following officers : Messrs. J. L. Baker, W. G. C. Breakey, M. W. Clifford, E. R. Comber, J. Copeland, P. J. Draper, H. M. Glover, H. H. Haines, R. G. A. Hannah, J. P. Haslett, J. N. Oliphant, and J. Whitehead.

EDWARD MARSDEN,

Silviculturist.

Summary of results of measurements in Divisional Sample Plots.

Species—*SHOREA ROBUSTA.*

United Provinces, Eastern Circle, Bahraich Division.

Sample Plot.	No. 1 W. C. I. Nishangara.	No. 2 W. C. I. Nishangara.	Combined.	No. 4 W. C. I. near Kakraha R. H.	No. 5 W. C. I. near Motipur R. H.	No. 6 W. C. III.	Combined.	No. 1 W. C. I. Nishangara.
Thinned or Unthinned.	Un-thinned.	Un-thinned.	Un-thinned.	Un-thinned.	Un-thinned.	Un-thinned.	Un-thinned.	Un-thinned.
Period of measurement.	1909—1914	1909—1914	1909—1914	1910—1916	1910—1916	1910—1916	1910—1916	1898—1909
Total number of measurements.	63	162	*225	106	107	96	309†	71‡

Rate of growth in girth.

Age in years.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
10	0 2½	0 4	0 4¼	0 4¼	0 3½	0 3½	0 3½	0 3¼
20	0 5¼	0 9¼	0 9¼	0 9½	0 7¾	0 7¾	0 7½	0 6½
30	0 8½	1 3¼	1 2¾	1 3	1 0	1 0¼	1 0	0 10
40	0 11¾	1 9½	1 8½	1 8¾	1 4¾	1 4¾	1 4¾	1 1½
50	1 1¼	2 3½	2 2½	2 2¼	1 9¼	1 9¼	1 9½	1 5½
60	1 6½	2 9½	2 8½	2 8½	2 2½	2 1¾	2 2¾	1 9½
70	1 10	3 3¼	3 2¼	3 2¾	2 8¼	2 6¼	2 8¼	2 2
80	2 2½	3 9	3 8	3 9¼	3 2	2 10¾	3 1¾	2 7½
90	2 7½	4 2½	4 1¾	4 4	3 7¼	3 3½	3 7½	3 1
100	3 1¼	4 7¾	4 7¾	4 10¾	4 0½	3 8¼	4 1	3 6½
110	3 7¼	5 1½	5 2¼	..	4 6	4 1¼	4 6¾	4 0½
120	4 1½	5 7½	5 9¼	..	4 11½	4 6	5 0¾	4 8
130	4 8½	..	..	..	5 5¼	4 10¾	5 6½	..
140	5 4¾	..	..	..	6 0¼	..	6 1¾	..
150	..	..	..	..	6 9	..	..	..

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—57 measts., 24″ to 36″—71 measts., 36″ to 48″—58 measts., 48″ to 60″—30 measts., 60″ to 72″—9 measts. = 225 measts.

† 0″ to 12″—No. of measts. *nil*, 12″ to 24″—52 measts., 24″ to 36″—97 measts., 36″ to 48″—82 measts., 48″ to 60″—61 measts., 60″ to 72″—14 measts., 72″ to 84″—3 measts. = 309 measts.

‡ 0″ to 12″—No. of measts. *nil*, 12″ to 24″—12 measts., 24″ to 36″—27 measts., 36″ to 48″—27 measts., 48″ to 60″—5 measts. = 71 measts.

Note.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA.*

United Provinces, Eastern Circle, Bahraich Division.

SAMPLE PLOT.	MURTIHA W. C. II.	MOTIPUR W. C. III.	No. 1 NISHANGARA W. C. I.	COMBINED.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Period of measurement .	1894—1898	1894—1898	1894—1898	1894—1898
Total number of measurements	55	46	57	158*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
10	0	5	0	4½	0	2¾	0	4½
20	1	0¼	0	9¾	0	6	0	9½
30	1	7½	1	3¼	0	10	1	3
40	2	3¼	1	9	1	2	1	9
50	2	11	2	3	1	6¼	2	3¼
60	3	7¼	2	8½	1	10¾	2	9½
70	4	3	3	1¾	2	4½	3	4
80	4	10¼	3	7	2	10¾	3	10¾
90	5	5½	..		3	5½	4	5¾
100	..		..		4	0¾	5	0¾
110	..		..		4	7¾	..	

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—39 measts., 24″ to 36″—63 measts., 36″ to 48″—43 measts., 48″ to 60″—10 measts., 60″ to 72″—3 measts. = 158 measurements.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

Summary of results of measurements in Forest Research Institute Sample Plo

Species—*SHOREA ROBUSTA.*

United Provinces, Eastern Circle, Bahraich Division.

Sample Plot.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	Combined sample plots 1, 2, 3, 4 &
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Thinned.	Unthinned
Descriptive details.	Flat alluvial ground; soil, a fertile loam, somewhat clayey on surface, becoming sandier at 3′ depth. Rather open, pure *Sal* forest of fair quality but trees somewhat crooked and some forked.	Flat alluvial land; soil, clayey loam. Pure *Sal* forest of fairly good quality. *Sal* regeneration very scanty.	Flat alluvial ground; soil, clayey loam. *Sal* forest of very good quality in tree stage. Some young *Sal* regeneration appearing.	Undulating ground. *Sal* forest of full height-growth and very good quality, lower *damar* type. Soil, sandy loam. No *Sal* regeneration. Very loose.	Flat alluvial ground; soil, a fertile loam. Dense, even-aged young *Sal* and *Sain* pole forest created by very heavy fellings about 30 years ago. Good quality, fully stocked.	Flat alluvial ground; soil, a fertile loam. Dense, even-aged young *Sal* and *Sain* pole forest created by very heavy fellings about 30 years ago. Good quality, fully stocked.	
Period of measurement.	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17
Total number of measurements.	32	16	32	27	45	36	152*

Rate of growth in girth.

Age in years.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. n.
10	0 2½	0 2¾	0 3¾	0 2¾	0 4¼	0 4¾	0 4½
20	0 5½	0 5¾	0 7¾	0 5¾	0 9½	0 10	0 9½
30	0 8¾	0 8¾	1 0½	0 8¾	1 3¼	1 3¾	1 3
40	1 0¼	1 0¼	1 5	1 0¼	1 9¾	1 10½	1 8¾
50	1 4¼	1 3¾	1 9¾	1 4	2 6	..	2 2½
60	1 8¼	1 7½	2 2½	1 8	..	..	2 7¾
70	2 0	1 11½	2 6½	2 0¼	..	..	3 1
80	2 3¾	2 4	2 11	2 4¾	..	..	3 6¼
90	2 7¼	2 9¼	3 3¼	2 9¼	..	..	3 11½
100	2 11¼	3 2¼	3 8¼	3 2½	..	..	4 5¾
110	3 3½	3 7½	4 1¼	3 8¾	..	..	4 11½
120	3 8½	..	4 6¾	4 3¼	..	..	5 4¼
130	4 2¼	..	4 11¾	4 9½	..	..	5 9
140	4 8¾	..	5 4¼	5 4½	..	..	..
150	5 2½	..	5 8¼	6 0	..	..	..
160	5 7½	..	6 0	..	..	..	..
170	6 0	..	..	..	..	..	..

* 0″ to 12″—No. of meásts. *nil*, 12″ to 24″—47 meásts., 24″ to 36″—37 meásts., 36″ to 48″—32 meásts.; 48″ to 60″—28 meásts., 60″ to 72″—8 meásts.=152 meásts.

Note.—Nothing has been added for the time required for the seedling to establish itself.

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SAMPLE PLOT.	No	No. 10.	COMBINED PLOTS 1 to 10.
Thinned or Unthinned.	Unth	Unthinned.	Unthinned.
Descriptive details	Flat loy. localn- clayest Pure el foresge fairlye, quali level large stage grow	Flat locality. Pure even-aged *Sal* forest, high-level type, in tree stage, good quality. No *Sal* reproduction.	
Period of measurement.	19 19	1911-12 to 1916-17	1911-12 to 1916-17.
Total number of measurements.		20	370*

Age in years.	Ft.	No. 10 Ft.	No. 10 in.	Combined Ft.	Combined in.	Age in years.
10	0	0	3¼	0	4½	10
20	0	0	6½	0	10	20
30	1	0	10¼	1	4¾	30
40	1	1	2¼	2	0	40
50	1	1	6¾	2	6	50
60	2	1	11	2	11¼	60
70	2	2	3¾	3	4½	70
80	3	2	8¼	3	9½	80
90	3	3	1¼	4	2¾	90
100	3	3	6¾	4	7¼	100
110		4	0¾	..		110
120		4	7¼	..		120
130		..		..		130
140		..		..		140
150		..		..		150
160		..		..		160
170		..		..		170
180		..		..		180
190		..		..		190

meas[ts.]

Summary of results of measurements in Forest Research Institute Sample Plots.

Species—*SHOREA ROBUSTA.*

United Provinces, Eastern Circle, Kheri Division.

Sample Plot.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	Combined Plots 1 to 10.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details	Flat low-lying locality : soil, clayey loam. Pure *Sal* forest of fairly good quality, low level type, large pole stage. Undergrowth *nil.*	Flat low-lying locality : soil, clayey loam. Pure *Sal* forest of fairly good quality, low level type, tree stage. Undergrowth *nil.*	Flat low-lying locality : soil, clayey loam. Small group of young *Sal* poles the result of regeneration in a small open grassy blank in which the grass is now becoming killed out.	Flat high-level alluvium : soil, clayey loam. Pure young *Sal* pole forest, high level type, fairly good quality, result of a group of regeneration sprung up in a grassy blank.	Low-level '*phanta*' belt type of pure *Sal* forest of good quality in large pole stage. Flat locality : soil, clayey loam. Fully stocked. Undergrowth *nil.*	Low-level '*phanta*' belt type of *Sal* forest in young pole stage. Flat locality : soil, clayey loam. Quality and type similar to No. 5, but in a much younger stage. Fully stocked. Undergrowth almost entirely a thick growth.	High-level *Sal* forest of good quality in large pole stage or young tree stage. Flat locality.	High-level *Sal* young pole forest of good quality. Flat locality. Soil loamy. Undergrowth practically *nil.*	Flat locality. Pure even-aged *Sal* forest of high-level type in large pole stage, good quality.	Flat locality. Pure even-aged *Sal* forest, high-level type, in tree stage, good quality. No *Sal* reproduction.	
Period of measurement.	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17.	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17	1911-12 to 1916-17.
Total number of measurements.	23	20	55	45	69	50	29	32	15	20	370*

Rate of growth in girth.

Age in years.	No. 1. Ft. in.	No. 2. Ft. in.	No. 3. Ft. in.	No. 4. Ft. in.	No. 5. Ft. in.	No. 6. Ft. in.	No. 7. Ft. in.	No. 8. Ft. in.	No. 9. Ft. in.	No. 10. Ft. in.	Combined Ft. in.	Age in years.
10	0 3	0 3¼	0 8	0 5¾	0 2¼	0 4½	0 4½	0 4½	0 3¼	0 3¼	0 4½	10
20	0 7½	0 6¾	1 5¼	1 0¼	0 5	0 10	0 9½	0 10	0 6½	0 6½	0 10	20
30	1 0¼	0 10¼	2 5¾	1 8¾	0 7¾	1 4¼	1 3¼	1 4¼	0 10¼	0 10¼	1 4¾	30
40	1 5¾	1 2¼	..	2 6	0 10¾	1 11½	1 9¾	1 11¾	1 2¼	1 2¼	2 0	40
50	1 11	1 6½	..	..	1 1¾	2 8¾	2 4¼	2 11	1 6¼	1 6¾	2 6	50
60	2 3¾	1 10¾	..	..	1 4¾	3 6	2 10¼	..	1 10½	1 11	2 11¼	60
70	2 7¾	2 3¼	..	..	1 8	..	3 5	..	2 3¼	2 3¾	3 4½	70
80	3 0¼	2 7½	..	..	1 11¼	..	3 11¼	..	2 8¼	2 8¼	3 9½	80
90	3 5	3 0¼	..	..	2 2½	..	..	..	..	3 1¼	4 2¾	90
100	3 10	3 5¼	..	..	2 5¾	..	..	..	..	3 6¾	4 7¾	100
110	..	3 10¼	..	..	2 9¼	..	..	..	..	4 0¾	..	110
120	..	4 4¼	..	..	3 0¼	..	..	..	..	4 7¼	..	120
130	..	4 10¼	..	..	3 3¾	..	..	..	..	..	..	130
140	..	..	..	..	3 7¼	..	..	..	..	..	..	140
150	..	..	..	..	3 10¾	..	..	..	..	..	..	150
160	..	..	..	..	4 1¾	..	..	..	..	..	..	160
170	..	..	..	..	4 4¾	..	..	..	..	..	..	170
180	..	..	..	..	4 7¼	..	..	..	..	..	..	180
190	..	..	..	..	4 10	..	..	..	..	..	..	190

* 0″ to 12″—3 measts., 12″ to 24″—197 measts., 24″ to 36″—95 measts., 36″ to 48″—62 measts., 48″ to 60″—13 measts.=370 measts.

Note.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA.*

Bengal Province, Darjeeling Division.

SAMPLE PLOT.	BADAMTOM.	PASHOK.	PASHOK.	RIANG.	RIANG.	COMBINED TISTA VALLEY.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Period of measurement.	1900—1910	1900—1909	1909—1917	1901—1910	1911—1916	1900—1917
Total number of measurements.	41	35	23	29	63	156*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
10	0	4½	0	3¾	0	3¾	0	3½	0	4¾	0	4¼
20	0	9½	0	7¾	0	8¼	0	7½	0	9¼	0	9¼
30	1	2¾	1	0¼	1	1¾	1	0	1	2¾	1	2¾
40	1	8¼	1	5	1	7¼	1	4¾	1	8¼	1	9
50	2	2	1	10	2	2	1	9½	2	1¾	2	4
60	2	8¾	2	3¾	2	10¼	2	3	2	7¾	2	11¾
70	3	3¼	2	9½	3	6	2	9	3	2¼	3	6¾
80	3	10¼	3	4	..		3	3¼	3	9¼	4	0¾
90	4	4½	3	10¼	..		3	9½	4	4½	4	6¼
100	4	9¾	4	3¾	..		4	3	5	0	4	11¼
110	5	2	4	8¾	..		4	8¼	5	7	5	3¾
120	5	5½	5	2¼	..		5	0¾	6	1	5	8
130	5	8¾	5	9	..		5	5¼	6	7¼	6	0
140	6	0	6	3	..		5	9¾	..		6	4¾
150	6	2¾	6	8¼	..		6	2¾	..		6	9
160	6	5¾	..		..		6	8¼	..		7	1¾
170	6	8¼	..		..		..		..		7	6½
180	6	11¼	..		..		..		..		7	11½

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—7 measts., 24″ to 36″—27 measts., 36″ to 48″—42 measts., 48″ to 60″—36 measts., 60″ to 72″—29 measts., 72″ to 84″—14 measts., 84″ to 96″—1 meast.=156 measts.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF HIGH FOREST MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA.*

Bihar and Orissa Province, Puri Division.

SAMPLE PLOT.	KADUAPARA.	RAJNI.	COMBINED.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.
Period of measurement .	1911—1916	1911—1916	1911—1916
Total number of measurements	66	67	133*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.
10	0	4	0	4¾	0	4¾
20	0	9¼	0	10¼	0	10
30	1	3	1	4½	1	3¾
40	1	8¾	1	11½	1	9¾
50	2	2¾	2	7	2	4½
60	2	9	3	3¼	2	11¼
70	3	3¼	4	0	3	7
80	3	9¾	4	9¼	4	2½
90	4	4¼	5	6½	4	10¾
100	4	11¼	..		5	6¾
110	5	6¼	..		..	

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—No. of measts. *nil*, 24″ to 36″—27 measts., 36″ to 48″—37 measts., 48″ to 60″—58 measts., 60″ to 72″—11 measts.=133 measts.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF MEASUREMENTS OF STANDARDS IN COPPICE.
DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA.*

Bihar and Orissa Province, Puri Division.

SAMPLE PLOT.	JAIMANGAL.	HARIPUR.	COMBINED.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.
Period of measurement . .	1911—1916	1911—1916	1911—1916
Total number of measurements .	44	70	114*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft	in.	Ft.	in.
10	0	3	0	3¾	0	3¼
20	0	6½	0	7¾	0	7
30	0	10¼	1	0¼	0	11¼
40	1	2	1	5	1	3½
50	1	6¼	1	10	1	8
60	1	10½	2	2¾	2	0¾
70	2	3½	2	8	2	5¾
80	2	9¼	3	1½	2	11¼
90	..		3	8	3	5¼
100	..		..		4	0

SUMMARY OF RESULTS OF HIGH FOREST MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA.*

Bihar and Orissa Province, Palamau Division.

SAMPLE PLOT.	KODARMA.	
Thinned or Unthinned.	Thinned.	Unthinned.
Period of measurement . . .	1911—1916	1911—1916
Total number of measurements .	93	97

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	n.
10	0	5½	0	5½
20	1	4½	1	4½

* 0″ to 12″—No. of measts. *nil,* 12″ to 24″—51 measts., 24″ to 36″—60 measts., 36″ to 48″—3 measts.=114 measts.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

Summary of results of high forest measurements in Divisional Sample Plots.

Species—*SHOREA ROBUSTA.*

Bihar and Orissa Province, Palamau Division.

Sample Plot.	Kari A.	Kari B.	Kusumbhkar.	Combined.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details.	Situated on a gentle slope having an aspect almost due east with a general cross fall southwards to the Kari river resting on the banks of a dry nallah 15′ to 20′ deep. Beyond the nallah at some distance the ground rapidly rises which protects the area from the morning sun. No *Sal* advance growth. A pit dug to a depth of 8′ 2″ shows a uniform sandy clay soil with a small admixture of small quartz fragments.	Old village lands. The plot is situated to the west of, and under the shadow of, the big Datrum Hill. The aspect is E. S. E. with a gentle cross slope to S. S. W. There is no *Sal* advance growth but an advance growth of *Jaman* shows the locality to be cool and favourable as regards sub-soil moisture. A pit dug to 8′ 1″ depth reveals a uniform sandy clay with a slight admixtureof small quartz fragments. Sub-soil is probably hornblende schist.	This plot is situated in the Ramandag Reserve on the north bank of the Koel river nearly opposite to the village of Heswa. The aspect is S. S. W. The soil on the surface appears to be a rich sandy loam and a pit dug to a depth of 5½ ft. shows the same soil to a depth of 2 ft. only. Below is a quartz gravel in a reddish clay matrix. Sub-soil is probably hornblende schists.	
Period of measurement.	1911—1916	1911—1916	1911—1916	1911—1916
Total number of measurements.	38	11	42	91*

Rate of growth in girth.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	in.
10	0	4¼	0	4½	0	4¾	0	4
20	0	10½	0	10¼	0	10½	0	10½
30	1	5	1	4¾	1	4¼	1	5
40	2	0¼	1	11¾	1	10¼	2	0
50	2	8¾	2	7	2	4¾	2	7½
60	..		3	3	2	11½	3	3¾
70	..		4	1	3	7½	4	1¼
80	..		5	0	4	5½	5	0

* 12″ to 24″—2 measts., 24″ to 36″—68 measts., 36″ to 48″—16 measts., 48″ to 60″—5 measts. = 91 measurements.

Note.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA Standards in Coppice.*

Bihar and Orissa Province, Palamau Division.

SAMPLE PLOT.	NEAR BURIA SOTE.	
Thinned or Unthinned.	Unthinned.	Unthinned.
Period of measurement	1906-07 to 1910-11	1910-11 to 1915-16
Total number of measurements . .	47*	43†

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.	Ft. in.
10	0 4¾	0 2¾
20	0 9¼	0 6¼
30	1 1¾	0 10¼
40	1 6½	1 2¼
50	1 11½	1 7
60	2 5½	2 0
70	..	2 6½

* 0″ to 12″—5 measts., 12″ to 24″—35 measts., 24″ to 36″—7 measts., =47 measts.

† 12″ to 24″—31 measts., 24″ to 36″—12 measts., =43 measurements.

SAMPLE PLOT.	M N	RANODI No. 5.	ALL PLOTS COMBINED.	
Thinned or Unthinned.	Unt	Unthinned.	Mixed.	
Descriptive details.	Nort atec neai hill. soil, mai Sur bou ove	sterly. Altitude slope, laterite of iron, manga- clay. Surface rocky boulders, ver.		
Period of measurement.	1903	1911 to 1916	1903 to 1916	
Total number of measurements.		93	609*	

Age in years	F	Ft.	in.	Ft.	in.	Age in years.
10	0	1	1¾	0	7¾	10
20	0	2	6	1	4¼	20
30	0	..		1	11½	30
40	1	..		2	4¾	40
50	1	..		2	9¾	50
60	1	..		3	2¾	60
70	2	..		3	7½	70
80	2	..		4	0½	80
90	2	..		4	5½	90
100	3	..		4	10½	100
110	3	..		..		110
120	3	..		..		120
130		..		..		130
140		..		..		140
150		..		..		150

easurements.

Summary of results of measurements in Divisional Sample Plots.

Species—*SHOREA ROBUSTA Coppice.*

Sonthal Parganas Division, Bihar and Orissa Province.

Sample Plot.	Majdiha No. 1.	Majdiha No. 1.	Kulkath No. 2.	Kulkath No. 2.	Katangi No. 3.	Katangi No. 3.	Kulkant No. 4.	Kulkant No. 4.	Ranodi No. 5	Ranodi No. 5.	All Plots Combined.	
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.	Thinned.	Unthinned.	Thinned.	Unthinned.	Mixed.	
Descriptive details.	North-western aspect, situated along the lower slope, near the base of Majdiha hill. Gradual slope, laterite soil, proportions of iron, manganese, sand and clay. Surface covered with rocky boulders, more or less all over.		Western aspect, situated along the lower slope near the base of Kulkath hill. Gradual slope, laterite soil, proportions of iron, manganese, sand and clay. Surface covered with rocky boulders, more or less all over.		Northern aspect, situated on flat land near the base of Khatangi hill. Gradual slope, laterite soil, proportions of iron, manganese, sand and clay. Surface covered with rocky boulders, more or less all over.		The aspect is westerly. Altitude 600 ft. Ground is sloping. Gradual slope, laterite soil, proportions of iron, manganese, sand and clay. Surface covered with rocky boulders, more or less all over.		The aspect is westerly. Altitude 800 ft. Gradual slope, laterite soil, proportions of iron, manganese, sand and clay. Surface covered with rocky boulders, more or less all over.			
Period of measurement.	1903 to 1909	1909 to 1915	1903 to 1909	1909 to 1915	1903 to 1909	1909 to 1915	1911 to 1916	1911 to 1916	1911 to 1916	1911 to 1916	1903 to 1916	
Total number of measurements.	42	44	45	33	46	19	93	100	94	93	609*	
Rate of growth in girth.												
Age in years	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Age in years.
10	0 2¾	0 2¼	0 4½	0 4¾	0 6	0 3¾	0 5¾	0 4½	0 10¾	1 1¾	0 7¾	10
20	0 6¾	0 5¼	0 10	0 10	1 2	0 8½	1 1¾	0 10½	2 0	2 6	1 4¼	20
30	0 10¾	0 8¾	1 3¼	1 3	1 9½	1 1½	1 10¼	1 4¾	..	..	1 11½	30
40	1 2¾	1 0	1 8¾	1 8	2 4¾	1 6½	..	1 11	..	..	2 4¾	40
50	1 6¾	1 3¼	2 2¼	2 0¾	2 11	1 11½	..	2 5	..	..	2 9¾	50
60	1 10½	1 6½	2 8	2 5½	3 5½	2 4½	..	2 11¼	..	..	3 2¾	60
70	2 2½	1 9¾	..	2 10½	4 0	2 9¾	...	..	..	..	3 7½	70
80	2 6¼	2 0¾	..	3 3½	4 7	3 3	..	..	..	..	4 0½	80
90	2 10¼	2 4	..	3 8¾	..	3 8	..	..	..	..	4 5½	90
100	3 2¼	2 7¼	..	..	..	4 0¾	..	..	..	..	4 10½	100
110	3 6¼	2 10¼	..	..	..	4 5½	..	..		..	..	110
120	3 10½	3 1½	..	..	..	4 10	..	..	..	..	..	120
130	..	3 4¾	..	..	..	..	..	..	..	..	..	130
140	..	3 8	..	..	..	..	..	..	..	..	..	140
150	..	3 11¼	..	..	..	..	..	..	..	..	..	150

* 0″ to 12″—167 measts., 12″ to 24″—277 measts., 24″ to 36″—133 measts., 36″ to 48″—28 measts., 48″ to 60″—4 measts. = 609 measurements.

Note.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA.*

Angul Division, Bihar and Orissa Province.

SAMPLE PLOT.	PURNAKOTE.	NIMBOCHALI.		PURNAKOTE.	ROSONDA.	COMBINED.
Thinned or Unthinned.	Unthinned.	Unthinned.		Unthinned.	Unthinned.	Unthinned.
Descriptive details.	Soil—Deep and fertile Rainfall about 50″. Aspect absolutely flat. Elevation about 500 ft. Between 20° 13′ and 21° 11′ north latitude and between 83° 47′ and 85° 16′ east longitude.	Soil—Fairly rich sandy loam. Rainfall about 60″. Aspect slightly sloping to west. Elevation about 1,200 ft. Between 20° 13′ and 21° 11′ north latitude and between 83° 47′ and 85° 16′ east longitude.		Soil—Deep and fertile. Rainfall about 50″. Aspect absolutely flat. Elevation about 500 ft. Between 20° 13′ and 21° 11′ north latitude and between 83° 47′ and 85° 16′ east longitude.	Soil—Fairly rich sandy loam. Rainfall about 60″. Aspect partially flat. Elevation about 2,000 ft. Between 20° 13′ and 20° 11′ north latitude and between 83° 47′ and 85° 16′ east longitude.	
Period of measurement.	1910 to 1914	1905 to 1909	1910 to 1914	1905 to 1909	1905 to 1909	4 years.
Total number of measurements.	25	39	6	56	71	197*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
10	..	..	0 4¼	..	..	..
20	..	..	0 9¼	..	..	..
30	2 0	1 3	1 2¾	1 0¾	1 0	1 2
40	2 9¼	1 9	1 9	1 5¾	1 4¼	1 7¼
50	3 7¾	2 3¼	2 3¼	1 10½	1 8½	2 0½
60	4 7¼	2 10	2 10	2 3¾	2 1¼	2 6½
70	..	3 5¼	3 5	2 9¼	2 5¾	3 0¾
80	..	4 0¾	4 0	3 3	2 10½	3 7¾
90	..	4 7¾	4 7	3 9½	3 3½	4 2¾
100	..	5 2½	..	4 4¾	3 8¾	4 10
110	..	5 9½	..	5 0¼	4 2¼	5 5½
120	..	6 5½	..	..	4 7¾	6 0
130	..	..	..	..	5 1¼	6 6¼
140	..	..	..	..	5 6½	7 0
150	..	..	..	..	6 0¼	7 5¾
160	..	..	..	..	6 6¼	7 11
170	..	..	..	..	6 11¾	..
180	..	..	..	..	7 5¼	..
190	..	..	..	..	7 10½	..

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—No. of measts. *nil*, 24″ to 36″—No. of measts. *nil*, 36″ to 48″—82 measts., 48″ to 60″—79 measts., 60″ to 72″—26 measts., 72″ to 84″—7 measts., 84″ to 9[illegible]″—3 measts. = 197 measurements.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA.*

Angul Division, Bihar and Orissa Province.

SAMPLE PLOT.	ROSONDA.	NIMBOCHALI.	COMBINED.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details .	Soil—Fairly rich sandy loam. Rainfall about 60″. Aspects partially flat. Elevation about 2,000 ft. Between 20° 13′ and 21° 11′ north latitude and between 83° 47′ and 85° 16′ east longitude.	Soil—Fairly rich sandy loam. Rainfall about 60″. Aspects slightly sloping to west. Elevation about 1,200 ft. Between 20° 13′ and 21° 11′ north latitude and between 83° 47′ and 85° 16′ east longitude.	
Period of measurement .	1911 to 1914	1911 to 1914	1911 to 1914
Total number of measurements.	41	50	91*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.
30	1	8½	2	1	1	8½
40	2	3½	2	10¼	2	3¾
50	2	10¾	3	7¼	2	11¼
60	3	5¾	4	5	3	7¼
70	4	1½	5	2¼	4	3¼
80	4	9	5	10½	4	11¾
90	5	5½	6	8	5	8½
100	6	2¼	..		6	7½
110	6	9¾	..		..	

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—No. of measts. *nil*, 24″ to 36″—No of measts. *nil*, 36″ to 48″—22 measts., 48″ to 60″—33 measts., 60″ to 72″—21 measts., 72″ to 84″—15 measts.=91 measurements.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

RD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

Bahraich Division, United Provinces.

Year of measurement.	Age of crop.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.							Remarks.
									Periodic yields.				Total to date.			
						Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	
11-12	..	*Shorea robusta* .	24″ and over. 137	45·5	94	3,929	1,000	4,929				Unthinned.				
			12″ to 24″ 67	18·2	45	..	205	205	..	..	..	..	..	..	..	
		TOTAL .	204	..	..	3,929	1,205	5,134	..	..	..	..	..	..	..	
916-17	..		24″ and over. 130	47·4	95	3,831	875	4,706	..	..	..	..	..	..	..	
			12″ to 24″ 26	17·5	40	..	20	20	..	..	..	..	..	..	..	
		TOTAL .	156	..	..	3,831	895	4,726	48	131	340	471	131	340	471	
1911-12	..	*Shorea robusta* .	24″ and over. 154	44·9	88	3,869	1,724	5,593				Unthinned.				
			12″ to 24″ 45	18·3	45	..	142	142	..	..	..	..	..	..	..	
		TOTAL .	199	..	..	3,869	1,866	5,735	..	..	..	..	..	..	..	
1916-17	..		24″ and over. 135	48·6	97	3,844	1,085	4,929	..	..	..	..	..	..	..	
			12″ to 24″ 35	18·1	46	..	97	97	..	..	..	..	..	..	..	
		TOTAL .	170	..	..	3,844	1,182	5,026	31	690	238	928	690	238	928	

RECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMP PLOTS—*contd.*

Bahraich Division, United Provinces—contd.

Number of Sample Plot.	Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½' from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET. Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	TOTAL TO DATE. Timber over 24" in girth.	Small wood 6"—24" girth.	Total.
5	1911-12	..	*Shorea robusta*	14" and over (green). 215	19·0	45	88	781	869					Unthinned.		
				6" to 14" (green). 946	8·9	26	..	420	420	..	..	..	..	..	..	..
				6" to 14" (dead and dying). 65	..	..	..	41	41	..	..	..	..	..	..	..
			Terminalia tomentosa	14" and over (green). 85	18·7	49	..	315	315	..	..	..	..	..	..	..
				6" to 14" (green) 246	9·5	28	..	138	138	..	..			Unthinned.		
				6" to 14" (dead and dying). 11	..	..	..	5	5	..	..	..	..	..	..	..
			Other species	14" and over (green). 8	21·0	39	..	25	25	..	..	..	..	..	..	..
				6" to 14" (green). 31	9·7	25	..	17	17	..	..	..	..	..	..	..
			TOTAL .	1,607	11·0	30	88	1,742	1,830	..	..	..	..	..	..	..
	1916-17	..		14" and over. 269	22·0	58	294	1,172	1,466	162	..	655	655	..	655	655
				6" to 14" 469	9·3	23	..	220	220	450	..	222	222	..	222	222
			TOTAL .	738	..	..	294	1,392	1,686	612	..	877	877	..	877	877

RECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS—*contd.*

Bahraich Division, United Provinces—contd.

Year of measurement.	Age of crop.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.							Remarks.
									Periodic yields.				Total to date.			
						Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	
			14″ and over (green).													
1911-12	..	*Shorea robusta*	169	17·6	44	..	535	535	Unthinned.							
			6″ to 14″ (green).													
			850	9·3	24	..	425	425	..	..	..	..	..	..	..	
			6″ to 14″ (dead and dying).													
			73	..	..	..	36	36	..	..	..	..	..	..	..	
			14″ and over (green).													
		Terminalia tomentosa	50	18·9	50	18	149	167	..	..	..	..	..	..	..	
			6″ to 14″ (green).													
			169	10·0	30	..	95	95	..	..	..	..	..	..	..	
			(dead and dying). 11	..	..	..	29	29	..	..	..	..	..	..	..	
			14″ and over (green).													
		Other species .	19	18·0	38	..	43	43	..	..	..	..	..	..	..	
			6″ to 14″ (green).													
			65	9·3	24	..	25	25	..	..	..	..	..	..	..	
		TOTAL .	1,406	10·9	28	18	1,337	1,355	..	..	..	..	..	..	..	
			14″ and over.													
1916-17	..		298	19·3	52	..	713	713	88	..	434	434	..	434	434	
			6″ to 14″ 342	10·0	29	..	244	244	381	..	310	310	..	310	310	
		TOTAL .	580	..	..	..	957	957	469	..	744	744	..	744	744	

RECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE P

Kheri Division, United Provinces.

Number of Sample Plot.	Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	TOTAL TO DATE. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.
1	1911-12	..	*Shorea robusta*	18″ and over. 384	27·7	63	1,288	2,200	3,488			Unthinned.				
				under 18″ 74	15·3	38	..	148	148	..	..	..	..	..	..	..
			TOTAL	458	..	..	1,288	2,348	3,636	..	..	..	..	..	..	..
	1916-17	..	*Shorea robusta*	22″ and over. 237	32·1	72	1,564	1,365	2,929	..	..	..	..	..	..	..
				20″ and less. 68	17·4	44	..	203	203	..	..	..	..	..	..	..
			TOTAL	305	..	..	1,564	1,568	3,132	147	254	770	1,024	254	770	1,024
	1911-12	..	*Shorea robusta*	18″ and over 254	35·5	71	2,952	1,378	4,330			Unthinned.				
				under 18″ 35	16·3	35	..	70	70	..	..	..	..	..	..	..
			TOTAL	289	..	..	2,952	1,448	4,400	..	..	..	..	..	..	..
	1916-17	..	*Shorea robusta*	24″ and over. 162	40·7	88	2,327	1,406	3,733	..	..	..	..	..	..	..
				under 24″ 54	19·2	40	..	170	170	..	..	..	..	..	..	..
			TOTAL	216	..	..	2,327	1,576	3,903	73	671	389	1,060	671	389	1,060

ECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS—*contd.*

Kheri Division, United Provinces—contd.

Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	TOTAL TO DATE. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	REMARKS.
1911-12	..	*Shorea robusta*	12″ and over. 356	16·2	32	..	694	694			Unthinned.					Open crop.
			6″ to 12″ 372	8·9	21	..	134	134	..	..	..	..	..	..	..	
		TOTAL .	728	..	..	..	828	828	..	..	..	..	..	..	..	
1916-17	..	*Shorea robusta*	12″ and over. 404	19·8	48	233	937	1,170	..	..	..	..	..	..	..	
			6″ to 12″ 232	8·6	21	..	74	74	..	..	..	..	..	..	..	
		TOTAL .	636	..	..	233	1,011	1,244	76	..	130	130	..	130	130	
1911-12	..	*Shorea robusta*	12″ and over. 453	15·5	41	..	886	886			Unthinned.					Dense crop.
			6″ to 12″ 740	8·6	21	..	206	206	..	..	..	..	..	..	..	
			under 6″ 647	..	..	..	..	..	..	..	..	..	..	..	..	
		TOTAL .	1,840	..	..	..	1,092	1,092	..	..	..	..	..	..	..	
1916-17	..	*Shorea robusta*	12″ and over. 480	18·0	44	..	1,166	1,166	..	..	..	..	..	..	..	
			6″ to 12″ 627	8·5	18	..	181	181	..	..	..	..	..	..	..	
			under 6″ 600	..	..	..	..	..	..	..	..	..	..	..	..	
		TOTAL .	1,707	..	..	..	1,347	1,347	193	..	316	316	..	316	316	

RECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLO —*contd.*

Kheri Division, United Provinces—contd.

Number of Sample Plot.	Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½' from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET. Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	TOTAL TO DATE. Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.
5	1911-12	..	*Shorea robusta*	18" and over. 433	31·2	72	3,130	2,337	5,467	Unthinned.						
				12" to 18" 112	15·1	43	..	229	229	..	..	..	..	..	..	..
			TOTAL .	545	..	..	3,130	2,566	5,696	..	..	..	..	..	..	
	1916-17	..	*Shorea robusta*	37" and over. 104	43·7	80	1,792	666	2,458	..	..	..	..	..	..	..
				24" to 36" 230	29·6	73	1,002	1,596	2,598	..	..	..	..	..	..	..
				12" to 23" 133	17·5	36	..	293	293	..	..	..	..	..	..	..
			TOTAL .	467	..	..	2,794	2,555	5,349	42	362	211	573	362	211	573
6	1911-12	..	*Shorea robusta*	12" and over. 447	20·1	50	434	1,586	2,020	Unthinned.						
				6" to 12" 805	8·9	24	..	291	291	..	..	..	..	..	..	..
			TOTAL .	1,252	..	..	434	1,877	2,311	..	..	..	..	..	..	..
	1916-17	..	*Shorea robusta*	12" and over. 379	22·8	57	702	1,298	2,000	..	..	..	..	..	..	..
				6" to 12" 458	9·0	25	..	148	148	..	..	..	..	..	..	..
			TOTAL .	837	..	..	702	1,446	2,148	337	..	459	459	..	459	459

ORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS —*contd.*

Kheri Division, United Provinces—contd.

							Volume per acre in solid cubic feet.			Intermediate yields per acre from thinning.							
										Total of date.				Periodic yields.			
	Year of measurement.	Age of crop.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Remarks.
	1911-12	..	*Shorea robusta*	18″ and over. 289	30·5	70	2,189	1,637	3,826			Unthinned.					Open crop.
				12″ to 18″ 194	14·3	36	..	286	286	..	..	..	..	..	..	..	
			Total .	483	..	..	2,189	1,923	4,112	..	..	..	..	..	..	..	
	1916-17	..	*Shorea robusta*	18″ and over. 300	31·0	81	1,949	2,330	4,279	..	..	..	..	..	..	..	
				12″ to 18″ 145	14·6	43	..	272	272	..	..	..	..	..	..	..	
			Total .	445	..	..	1,949	2,602	4,551	28	375	206	581	375	206	581	
8	1911-12	..	*Shorea robusta*	12″ and over. 260	16·1	43	..	666	666			Unthinned.					Dense crop.
				6″ to 12″ 605	8·5	28	..	180	180	..	..	..	..	..	..	..	
			Total .	865	..	..	..	846	846	..	..	..	..	..	..	..	
	1916-17	..	*Shorea robusta*	12″ and over. 330	17·8	56	..	971	971			Unthinned.					
				6″ to 12″ 530	8·5	27	..	210	210	..	..	..	..	..	..	..	
			Total .	860	..	..	..	1,181	1,181	..	..	..	..	..	..	..	
9	1911-12	..	*Shorea robusta*	16″ and over. 375	25·3	69	1,069	2,280	3,349			Unthinned.					Dense crop.
				10″ to 16″ 317	13·1	36	..	499	499	..	..	..	..	..	..	..	
			Total .	692	..	..	1,069	2,779	3,848	..	..	..	..	..	..	..	
	1916-17	..	*Shorea robusta*	16″ and over. 367	25·2	71	1,138	1,939	3,077	..	..	..	..	..	..	..	
				10″ to 16″ 217	12·9	32	..	202	202	..	..	..	..	..	..	..	
			Total .	584	..	..	1,138	2,141	3,279	42	129	487	616	129	487	616	

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA Coppice.*

Palamau Division, Bihar and Orissa Province.

SAMPLE PLOT.	KODARMA.	KODARMA
Thinned or Unthinned.	Unthinned.	Thinned.
Descriptive details	Latitude 85° 37′ 30″, Longitude 24° 30′ 0″, Rainfall 50·82 inches. Aspect south-westerly. Elevation 1,190 ft. Soil, sandy clay. The plot is situated in square 27e (small) of the Kodarma Reserved forest, which formed the departmental coupe of 1908-09.	
Period of measurement . . .	1911 to 1916	
Total number of measurements . .	80	83

RATE OF GROWTH IN HEIGHT.

Age in years.	Corresponding height. Ft.	Corresponding height. Ft.
5	12	7½
10	24	19¼

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*SHOREA ROBUSTA Coppice.*

Bihar and Orissa Province, Sonthal Parganas Division.

SAMPLE PLOT.	KULKANT No. 4.	KULKANT No. 4.	RANODI No. 5.	RANODI No. 5.	ALL PLOTS COMBINED.
Thinned or Unthinned.	Thinned.	Unthinned.	Thinned.	Unthinned.	Mixed.
Descriptive details .	The aspect is westerly. Altitude 600 ft. Ground is sloping. Gradual slope, laterite soil, proportion of iron, manganese, sand and clay. Surface covered with rocky boulders, more or less all over.		The aspect is westerly. Altitude 800 ft. Ground is sloping. Gradual slope, laterite soil, proportion of iron, manganese, sand and clay. Surface covered with rocky boulders more or less all over.		
Period of measurement.	1911-1916	1911-1916	1911-1916	1911 1916	1911-1916
Total number of measurements.	77	84	91	91	343*

RATE OF GROWTH IN HEIGHT.

Age in years.	Corresponding height. Ft.	Corresponding height. Ft.	Corresponding height. Ft.	Corresponding height. Ft.	Corresponding height. Ft.
10	30¾	21¾	29¾	40	31½
20	48	38¾	..	..	50¼
30	58¾	53¼	..	..	61½

*0″ to 12″—No. of measts. *nil*, 12″ to 24″—57 measts., 24″ to 36″—152 measts., 36″ to 48″—110 measts., 48″ to 60″—24 measts., =343 measurements.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

Summary of results of measurements in Divisional Sample Plots.

Species—*ACACIA CATECHU.*

Palamau Division, Bihar and Orissa Province.

Sample Plot.	Kerb (A).	Kerb (B).	Kechki.	All Combined. S. Plots.
Thinned or Unthinned.	Unthinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details .	The plot is situated in the same tongue of the Saidope Reserve as Kerb (B), but further west and quite close to the outer boundary near Boundary Pillar. The aspect is S. S. W. The soil is stiffer than that found in (B) plot, free from broken quartz fragments and the underlying sand was not found. The subsoil is probably the same as in (B). The plot is well drained like (B) extending to the bottom of a dry nallah.	The plot is situated in a tongue of forest about a mile in width forming the N. E. corner of the Saidope Reserve and about a quarter of a mile west of Boundary Pillar No. 20. The aspect is south-easterly. The area is well-drained. The soil is a sandy clay from decomposed gneiss mixed with broken fragments of quartz. A pit 4′ deep showed that the upper layer of $2\frac{1}{2}$′ is yellow brown in colour and below almost pure sand gray and nearly dry is found. The soil is apparently of good depth and subsoil is hornblende schists.	This plot is situated in the Reserved forest of the same name in the portion lying to the east of the Kechki Barasand road. The aspect is Northerly. Soil clay.	
Period of measurement.	1911 to 1916	1911 to 1916	1911 to 1916	1911 to 1916
Total number of measurements.	28	51	38	117*

Rate of growth in girth.

Age in years.	Ft.	in.	Ft.	in.	Ft.	in.	Ft	in.
30	..		0	$6\frac{1}{4}$	0	$4\frac{3}{4}$	0	$4\frac{3}{4}$
40	0	$6\frac{1}{4}$	0	$9\frac{1}{2}$	0	$8\frac{1}{4}$	0	$7\frac{1}{2}$
50	0	$8\frac{3}{4}$	1	$0\frac{1}{2}$	1	0	0	$10\frac{1}{4}$
60	0	$10\frac{3}{4}$	1	$3\frac{3}{4}$	1	$3\frac{3}{4}$	1	$0\frac{3}{4}$
70	1	$1\frac{1}{4}$	1	$7\frac{1}{2}$	1	$7\frac{1}{4}$	1	$3\frac{1}{2}$
80	1	$4\frac{1}{4}$	1	$11\frac{1}{2}$	1	11	1	7
90	1	$7\frac{1}{2}$	2	4	2	$3\frac{3}{4}$	1	$10\frac{1}{2}$
100	1	$10\frac{3}{4}$	2	9	2	$8\frac{3}{4}$	2	$2\frac{3}{4}$
110	..		..		3	$1\frac{3}{4}$	2	$7\frac{1}{2}$
120	..		..		3	$6\frac{1}{2}$	3	$0\frac{3}{4}$
130	..		..		3	$11\frac{1}{4}$	3	7

* 12″ to 24″—75 measts., 24″ to 36″—40 measts., 36″ to 48″—2 measts.=117 measts.

Note.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*TERMINALIA TOMENTOSA.*

Bahraich Division, Eastern Circle, United Provinces.

SAMPLE PLOT.	No. 5.	No. 6.
Thinned or Unthinned.	Unthinned.	Thinned.
Descriptive details	Flat alluvial ground ; soil, a fertile loam. Dense, even-aged young *Sal* and *Sain* pole forest created by very heavy fellings about 30 years ago. Good quality, fully stocked.	
Period of measurement . . .	1911-12 to 1916-17	1911-12 to 1916-17
Total number of measurements . .	20*	10†

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.	Ft.	in.
10	0	5¾	0	3¾
20	1	0	0	7¾
30	1	7½	1	0¼
40	2	3¼	1	5¾
50	..		1	11¾
60	..		2	7

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—18 measts., 24″ to 36″—2 measts.=20 measts.
† 0″ to 12″—No. of measts. *nil*, 12″ to 24″—8 measts., 24″ to 36″—2 measts.=10 measts.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

TERMINALIA TOMENTOSA.

Balaghat Division, Southern Circle, Central Provinces.

SAMPLE PLOTS.	ALL SAMPLE PLOTS IN BAIHAR AND RAIGARH RANGE
Thinned or Unthinned.	Unthinned.
Period of measurement . . .	1907—1915
Number of measurements . . .	39*

RATE OF GROWTH IN GIRTH.

Age in years.	Ft.	in.
10	..	
20	0	3½
30	0	6
40	0	9
50	1	0
60	1	2¾
70	1	5¼
80	1	8
90	1	10¾
100	2	1¼
110	2	4
120	2	6¾
130	2	9¼
140	3	0

* 0″ to 12″—3 measts., 12″ to 24″—34 measts., 24″ to 36″—2 measts.=39 measts.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

SUMMARY OF RESULTS OF MEASUREMENTS IN DIVISIONAL SAMPLE PLOTS.

SPECIES—*DUABANGA SONNERATIOIDES.*

Darjeeling Division, Bengal Province.

SAMPLE PLOT.	SAMBONG III.		MANGWA V.		COMBINED.	
Thinned or Unthinned.	Unthinned.		Unthinned.		Unthinned.	
Period of measurement . .	1911 to 1917		1906 to 1910		1906 to 1917	
Total number of measurements.	35		20		55 *	
RATE OF GROWTH IN GIRTH.						
Age in years.	Ft.	in.	Ft.	in.	Ft.	in.
10	1	0½	2	2	1	10¼
20	3	0¾	3	9	3	2
30	3	10¼	..		4	2½
40	4	8	..		5	2¾
50	5	6½	..		6	4
60	6	5½	..		7	4½
70	7	4¼	..		..	

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—6 measts., 24″ to 36″—8 measts., 36″ to 48″—10 measts., 48″ to 60″—9 measts., 60″ to 72″—16 measts., 72″ to 84″—5 measts., 84″ to 96″—1 meast. = 55 measts.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

RECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE PLOT.

SPECIES—*CINNAMOMUM CAMPHORA.*

Experimental Garden, Dehra Dun.

Number of Sample Plot.	Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	TOTAL TO DATE. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	REMARKS.
3	1914-15	17	*Cinnamomum Camphora.*	561	17·5	53	109	2,257	2,366	492	..	885	885	..	885	885	Plantation.
	1916-17	19	-	383	21·2	54	570	1,743	2,317	183	..	648	648	..	1,533	1,533	

Summary of results of measurements in Forest Research Institute Sample Plots.

Species—*QUERCUS SEMECARPIFOLIA.*

Chakrata Division, Western Circle, United Provinces.

Sample Plot.	No. 1.	No. 3.	Combined.	No. 2.	No. 4.	Combined
Thinned or Unthinned.	Thinned.	Thinned.	Thinned.	Unthinned.	Unthinned.	Unthinned
Descriptive details.	At Deoban. Mohna Block C., 9. Alt. 9,000′ aspect, south-east, Slope 38°; soil, moist and fertile. Kharshu oak forest in large pole stage, fully stocked, undergrowth of ringals, shrubs, and herbaceous growth. A few young Kharshu seedlings.	At Deoban. Alt. 9,000′; slope 36°. Soil, moist and fertile. Kharshu oak forest in pole stage; undergrowth of shrubs and herbaceous growth. Numerous Kharshu seedlings 1 or 2 years old.		Adjoining, and immediately to the N. and E. of plot No. 1, and exactly similar to it in every respect.	Adjoining, and immediately to the N. and E. of No. 3, which it resembles in every respect.	
Period of measurement.	1911-12 to 1916-17			1911-12 to 1916-17		
Total number of measurements.	24	22	46 *	40	44	84 †

Rate of growth in girth.

Age in years.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
10	0 2¾	0 2¼	0 2½	0 1¼	0 2½	0 1¾
20	0 6¾	0 5¾	0 5¾	0 3½	0 5½	0 4¼
30	0 10¼	0 9½	0 9¾	0 6¼	0 8¾	0 7¼
40	1 2	1 1¾	1 2	0 9	1 0	0 10½
50	1 6	1 5¾	1 6	1 0	1 3½	1 1¾
60	1 10	1 9¾	1 10	1 2¾	1 6¾	1 4¾
70	2 2¾	2 2¼	2 2¾	1 5¾	1 10¼	1 8
80	2 8	2 7¼	2 7¾	1 8¾	2 2	1 11½
90	..	3 1	3 1¼	1 11¾	2 5¾	2 3
100	..	3 7	3 7½	2 3½	2 9¼	2 6¾
110	..	..	..	2 7¼	..	2 10¾
120	..	..	..	2 11¼	..	3 3

* 12″ to 24″—38 measts., 24″ to 36″—7 measts., 36″ to 48″—1 meast.=46 measts.

† 0″ to 12″—1 meast., 12″ to 24″ —74 measts., 24″ to 36″—7 measts., 36″ to 48″—1 meast., 48″ to 60″—1 meast.=84 measts.

Note.—Nothing has been added for the time required for the seedling to establish itself.

CORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

Chakrata Division, United Provinces.

Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½' from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET.			INTERMEDIATE YIELDS PER ACRE FROM THINNINGS.							REMARKS.
									PERIODIC YIELDS.				TOTAL TO DATE.			
						Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	Number of stems.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	Timber over 24" in girth.	Small wood 6"—24" in girth.	Total.	
1911-12	..	*Quercus semecarpifolia.*	1,301	15·5	30	..	3,015	3,015	923	..	833	833	..	833	833	
1916-17	..		1,269	17·6	34	..	3,373	3,373	86	..	106	106	..	939	939	
1911-12	..	Ditto	2,076	15·9	30	..	5,201	5,201	..		Unthinned.					
1916-17	..		1,903	19·0	37	..	7,070	7,070	..	..	..	..	..	..	..	
1911-12	..	Ditto	900	18·7	32	..	3,062	3,062	590	..	789	789	..	789	789	
1916-17	..		815	22·4	38	..	3,440	3,440	28	..	84	84	..	873	873	
1911-12	..	Ditto	2,509	15·9	29	..	4,556	4,556	..		Unthinned.					
1916-17	..		2,472	17·9	37	..	6,250	6,250	..	..	..	..	..	..	..	

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*QUERCUS INCANA.*

Experimental Garden, Dehra Dun, United Provinces.

SAMPLE PLOT.	No. 2.
Thinned or unthinned.	Thinned.
Descriptive details	Fertile clayey loam, arable land. Density full. Undergrowth almost absent. Plantation in young pole stage.
Period of measurement . . .	1912-13 to 1916-17.
Total number of measurements . .	56 *

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.
10	0 4½
20	0 9½
30	1 3½
40	1 11¼
50	2 10¾

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—42 measts., 24″ to 36″—14 measts. = 56 measts.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

RECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE PLOTS.

Experimental Garden, Dehra Dun, United Provinces.

Number of Sample Plot.	Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	INTERMEDIATE YIELDS PER ACRE FROM THINNINGS. PERIODIC YIELDS. Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	TOTAL TO DATE. Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	
2	1912-13	32	*Quercus incana*	525	20·6	56	..	3,208	3,208	364	..	950	950	..	950	950	Plantation.
	1916-17	36		356	26·6	65	..	3,827	3,827	169	..	658	658	..	1,608	1,608	

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*PINUS EXCELSA.*

Chakrata Division, Western Circle, United Provinces.

SAMPLE PLOT.	No. 9.	No. 10.
Thinned or Unthinned.	Thinned.	Unthinned.
Descriptive details . .	At Koti Kanasar, in compt. 25, N.-E. Elevation about 7,700′, slope 37°. Pure Kail forest hitherto densely stocked, now thinned, sprung up naturally on old cultivation, the result of fire-protection. No undergrowth. Underlying rock-limestone shale; soil, deep and fertile.	At Koti Kanasar, in compt. 25, Aspect N. E. Elevation about 7,700′, slope 30°. Pure Kail forest densely stocked, sprung up on old cultivation, naturally the result of fire-protection. No undergrowth. Underlying rock-limestone shale; soil, deep and fertile.
Period of measurement .	1911-12 to 1916-17.	
Total number of measurements.	61 *	136 †

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.	Ft. in.
10	0 4¼	0 2¼
20	0 9¼	0 4¾
30	1 3	0 7¼
40	1 9½	0 11
50	2 5	1 2¾
60	3 2¾	1 6¼
70	4 5¼	1 10
80	..	2 3¾
90	..	2 11½
100	..	3 10¾

* 12″ to 24″—24 measts., 24″ to 36″—31 measts., 36″ to 48″—5 measts., 48″ to 60″—1 meast.=61 measurements.

† 12″ to 24″—69 measts., 24″ to 36″—64 measts., 36″ to 48″—3 measts.=136 measurements.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

ECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

Chakrata Division, United Provinces.

Year of measurement.	Age of crop.	Species.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	Volume per acre in solid cubic feet.			Intermediate yields per acre from thinnings.							Remarks.
									Periodic yields.				Total to date.			
						Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	
1911-12	33	*Pinus excelsa*	456	24·9	61	1,315	1,931	3,246	1,315	366	2,055	2,421	366	2,055	2,421	
1916-17	38		283	31·2	75	1,991	1,030	3,021	171*	..	926*	926	366	2,981	3,347	
1911-12	33	Ditto	657	23·1	58	1,352	2,977	4,329	..	..	..	..	..	..	..	Dominant and dominated.
			1,743	..	..	211	1,566	1,777	..	..	..	..	..	..	..	Suppressed and dead.
		Total	2,400	..	..	1,563	4,543	6,106	..	..	..	..	..	..	..	
1916-17	38	..	650	26·2	70	2,390	2,485	4,875	..	..	..	..	..	..	..	Dominant and dominated.
			1,493	..	..	267	1,587	1,854	..	..	..	..	..	..	..	Suppressed and dead.
		Total	2,143	..	..	2,657	4,072	6,729	..	..	..	..	..	..	..	

* Stems broken or uprooted by snow during quinquennium.

SPECIES—*PINUS EXCELSA.*

HEIGHT INCREMENT.

Calculated from ring countings at stump of 25 trees in Pabar Range compartment 29, Bashahr Division, Punjab. Data collected by Divisional staff in 1915-16.

Age in years.	Height in feet.		
	Maximum.	Average.	Minimum.
30	28	..	..
35	36	..	..
40	43	33	..
45	48	38	..
50	53	42	19
55	57	45	23
60	61	48	26
65	64	51	29
70	67	54	31
75	70	57	33
80	..	..	35

Age in years.	Diameter increment at 2 ft. from ground.
	(inches.)
10	2·9
15	4·3
20	6·3
25	8·0
30	9·6
35	11·1
40	12·6
45	14·1
50	15·6
55	17·1
60	18·6

OUTTURN.

In Pabar Range, compartment 29, Bashahr Division, Punjab, curves prepared from measurements of the outturn from 25 trees showed the following :—

Height of tree.	Length of useful bole.	Outturn in converted scantlings.
(feet.)	(feet.)	(cub. feet.)
30	24	5½
35	28	7
40	32	9
45	36	11
50	40	13
55	44	15
60	48	18
65	52	23
70	57	30
75	62	45

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*PINUS LONGIFOLIA.*

Experimental Garden, Dehra Dun, United Provinces.

SAMPLE PLOT.	NO. 1.
Thinned or Unthinned.	Thinned.
Descriptive details	Fertile clayey loam. Arable land. Density full. Plantation in big pole stage.
Period of measurement .	1912-13 to 1916-17.
Total number of measurements .	31 *

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.
10	0 5
20	1 10
30	2 10
40	3 10
50	5 3

* 0″ to 12″—No. of measts. *nil*, 12″ to 24″—2 measts., 24″ to 36″—11 measts., 36″ to 48″—16 measts., 48″ to 60″— 2 measts.=31 measts.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

RECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

Experimental Garden, Dehra Dun, United Provinces.

Number of Sample Plot.	Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET.			INTERMEDIATE YIELDS PER ACRE FROM THINNINGS.							REMARKS.
										PERIODIC YIELDS.				TOTAL TO DATE.			
							Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ girth.	Total.	
1	1912-13	30	*Pinus longifolia*	322	38·7	79	6,353	1,678	8,031	139	494	615	1,109	494	615	1,109	Plantation.
	1916-17	34		252	45·4	93	7,396	407	7,803	70	888	295	1,183	1,382	910	2,292	

SUMMARY OF RESULTS OF MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLOTS.

SPECIES—*CEDRUS DEODARA.*

Chakrata Division, Western Circle, United Provinces.

SAMPLE PLOT.	No. 5.	No. 7.	COMBINED.	No. 6.	No. 8.	COMBINED.
Thinned or Unthinned.	Thinned.	Thinned.	Thinned.	Unthinned.	Unthinned.	Unthinned.
Descriptive details.	At Konain, compt. 26. Elevation 7,800′; aspect N. E.; slope 39°. Pure deodar plantation 4′ × 4′, planted 1876 [seed sown in nursery 1872.] Little or no undergrowth. Cold, rather moist locality; surrounding forest chiefly deodar, spruce and moru oak, with blue pine on the ridges.	At Konain, compt. 26. Elevation 7,800′; aspect N.; slope 21°. Locality and soil good. Pure deodar forest in large pole or young tree stage. Thinning made, and all existing Kail trees removed.		Immediately to N. of, and exactly similar to plot No. 5, which it adjoins.	At Konain, compt. 26. Elevation 7,800′; aspect N.; slope 24°. Locality and soil good. Pure deodar forest (with 2 Kail trees) in large pole or young tree stage. Not thinned. Locality and type of forest exactly similar to plot No. 7.	
Period of measurement	1911-12 to 1916-17.			1911-12 to 1916-17.		
Total number of measurements.	49	28	77 *	65	38	103 †

RATE OF GROWTH IN GIRTH.

Age in years.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
10	0 1¾	0 2¼	0 1¾	0 1¾	0 1½	0 1½
20	0 4¾	0 5	0 4¼	0 4¼	0 3¾	0 3¾
30	0 8	0 8½	0 7½	0 7¼	0 6¾	0 6¾
40	1 0	1 0½	1 0	0 10¼	0 10	0 10
50	1 5¾	1 5¼	1 5¼	1 2¼	1 2	1 2
60	1 10½	1 10¼	1 10½	1 6¾	1 6¾	1 6¾
70	2 5	2 2½	2 3¾	1 11½	1 11¼	1 11¼
80	3 0	2 7	2 9¼	..	2 3¾	2 3¾
90	..	2 11¾	3 3¼	..	2 8	2 8
100	..	3 6¼	3 9¼	..	3 0½	3 0½
110	..	3 9½	4 3¼	..	3 4¾	3 4¾
120	..	4 3½	4 9¼	..	3 9¼	3 9¼
130	..	4 9¼	..	..	4 2¾	4 2¾
140	..	..	..	..	4 9¼	4 9¼
150	..	..	..	..	5 4¼	5 4¼
160	..	..	..	..	5 11¼	5 11¼

* 0″ to 12″—8 measts., 12″ to 24″—37 measts., 24″ to 36″—8 measts., 36″ to 48″—16 measts., 48″ to 60″—8 measts. = 77 measurements.

† 0″ to 12″—18 measts., 12″ to 24″—47 measts., 24″ to 36″—21 measts., 36″ to 48″—11 measts., 48″ to 60″—4 measts., 60″ to 72″—2 measts. = 103 measurements.

NOTE.—Nothing has been added for the time required for the seedling to establish itself.

RECORD OF PERIODICAL VOLUME MEASUREMENTS IN FOREST RESEARCH INSTITUTE SAMPLE PLO

Chakrata Division, United Provinces.

Number of Sample Plot.	Year of measurement.	Age of crop.	SPECIES.	Number of stems per acre.	Mean girth at 4½′ from ground.	Mean height of crop in feet.	VOLUME PER ACRE IN SOLID CUBIC FEET.			INTERMEDIATE YIELDS PER ACRE FROM THINNINGS.							REMARKS.
										PERIODIC YIELDS.				TOTAL TO DATE.			
							Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Number of stems.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	Timber over 24″ in girth.	Small wood 6″—24″ in girth.	Total.	
5	1911-12	39	*Cedrus Deodara*	1,556	15·2	34	..	2,472	2,472	463	..	541	541	..	541	541	Plant tic
	1916-17	44		1,556	17·2	43	..	3,834	3,834	..	..	..	..	..	..	..	
6	1911-12	39	Ditto	1,772	13·2	30	..	2,315	2,315	(Unthinned.)							Planta tio
	1916-17	44		1,316	14·9	40	..	2,109	2,109	456	..	296	296	..	296	296	
7	1911-12	50	Ditto	227	40·5	68	4,449	732	5,181	267	1,388	992	2,380	1,388	992	2,380	Natur Fores
	1916-17	55		187	44·8	81	4,386	541	4,927	40	520	164	684	1,908	1,156	3,064	
8	1911-12	45	Ditto	517	35·1	61	049	1,880	7,929	(Unthinned.)							Natur Fores
	1916-17	50		500	37·6	77	7,677	2,056	9,733	..	..	..	..	..	..	..	

SPECIES—*CEDRUS DEODARA.*

HEIGHT INCREMENT.

Calculated from ring countings at stump of 93 trees in Pabar Range Compartment 30, Bashahr Division, Punjab. Data collected by Divisional staff in 1915-16.

Age in years.	Height in feet.		
	Maximum.	Average.	Minimum.
15	21	..	..
20	31	..	..
25	41	30	..
30	51	37	11
35	60	43	16
40	68	49	21
45	75	54	26
50	81	59	31
55	87	63	36
60	92	67	40
65	..	..	44
70	..	..	48
75	..	..	51

Age in years.	Diameter Increment at 2 ft. from ground.
	Diameter in inches.
5	1·7
10	3·6
15	6·0
20	8·4
25	10·8
30	12·8
35	14·8
40	16·8
45	18·7
50	20·3
55	21·8
60	23·3

Species—*CEDRUS DEODARA.*

Outturn.

In Pabar Range Compartment 30, Bashahr Division, Punjab, curves prepared from measurements of the outturn from 93 trees showed the following :—

(Data collected by Divisional staff 1915-16.)

Height of tree.	Length of useful bole.	Outturn in converted scantlings.
(feet.)	(feet.)	(cub. feet.)
30	22	7
35	26	8½
40	31	11
45	35	14
50	39	17
55	43	20
60	47	30
65	51	41
70	55	49
75	60	58

Stem analysis of a Cedrus Deodara *tree in Chakrata Division near Konain, compartment 26. Elevation 7,800′, aspect N., Slope 21°. Locality and soil good. Pure deodar forest in large pole or young tree stage. Age, 57 years. Total height, 63 feet. Girth at b.-h., 35 inches.*

(Data collected by the Forest Research Institute.)

Age (years).	Height (feet).	Diameter (inches) at a height of							Volume * (cub. ft.)
		5′	15′	25′	35′	45′	55′	60′	
5	1	..	..	..	..	..	..	..	..
10	3	..	..	..	..	..	..	..	..
15	5	..	..	..	..	..	..	..	..
20	12	1·0	..	..	..	..	..	..	..
25	20	2·5	1·4	..	..	..	..	..	·4
30	29	4·2	3·5	1·8	..	..	..	..	1·8
35	37	5·9	5·5	5·1	1·3	..	..	..	4·6
40	44	7·4	7·2	5·9	3·6	..	..	..	8·6
45	51	8·9	8·1	7·2	5·5	1·4	..	..	12·3
50	58	9·8	8·6	7·8	6·5	3·1	·3	..	15·4
55	..	10·0	9·0	8·0	6·8	2·5	1·4	·3	17·1

* Volume calculated by πr^2 method.

COMPARATIVE GROWTH OF NATURAL AND PLANTATION SAPLINGS,

(*Data collected by the Forest Research Institute.*)

The development of Deodar saplings growing in a natural crop and in a plantation was studied at Konain, Chakrata Division, United Provinces, by preparing stem analyses of 18 natural saplings and of 14 plantation saplings. Sections were cut at every 5 feet in height of the 32 trees. The natural saplings ranged in height from 29 to 46 feet, in age from 34 to 46 years, and in girth from 12·8 to 17·1 inches. The plantation saplings ranged in height from 32 to 44 feet, in age from 32 to 42 years, and in girth from 11·1 to 19·2 inches. The early development of natural saplings was calculated from observation in experimental plots.

The arithmetical mean of the 18 natural saplings showed : Age 40 years, Height 37 feet, Quarter-girth Volume 1·73 cubic feet. Form factor ·50. The arithmetical mean of the 14 plantation saplings showed : Age 37 years, Height 37 feet, Quarter-girth Volume 1·58 cubic feet. Form factor ·48.

(*i*) *Growth in Height of Deodar saplings in a Natural crop and in a Plantation.*

Age in years.	Height in feet.					
	Natural crop.			Plantation.		
	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.
5	..	½	..	3	2	1½
10	4½	1½	..	9¼	5½	3¾
15	9½	5	2	16½	11	7¼
20	16	10	4½	23½	16½	12
25	25	16½	9	31	22½	17
30	38	24	14	..	28½	22½
35	..	32	19½	..	34½	27½
40	..	41	27½	..	42	..

(*ii*) Proportion of Heart-wood and Sap-wood.

At a height of	Diameter in inches.		
	Heart-wood.	Sap-wood.	Total.
Natural saplings. Age 40. Average of 18 trees.			
5′	1·2	3·1	4·3
10′	·6	3·5	4·1
15′	·3	3·1	3·4
20′	..	2·6	2·6
25′	..	2·0	2·0
30′	..	1·6	1·6
Plantation saplings. Age 37. Average of 14 trees.			
1′	1·9	2·3	4·2
5′	1·6	2·2	3·8
10′	·6	2·8	3·4
15′	·2	2·9	3·1
20′	·1	2·5	2·6
25′	..	2·1	2·1
30′	..	1·3	1·3
35′	..	·7	·7

(*iii*) Bark Thickness.

Same for Natural and Plantation crops.

Average of 31 saplings, 37 ft. high.

Height in feet.	Bark thickness in inches.
1	·22
5	·19
10	·16
15	·13
20	·10
25	·08
30	·05
35	·03

(iv) Growth in Diameter (without bark) of Deodar saplings in a Natural crop.

Age in years.	DIAMETER IN INCHES.																
	MAXIMUM. At a height of						AVERAGE. At a height of						MINIMUM. At a height of				
	5′	10′	15′	20′	25′	30′	5′	10′	15′	20′	25′	30′	5′	10′	15′	20′	25′
12	·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
14	·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
16	1·2	..	..	..	..	..	·2	..	..	..	..	..	..	..	..	..	..
18	1·6	·6	..	..	..	..	·6	..	..	..	..	..	..	..	..	..	..
20	1·9	1·2	·1	..	..	..	·9	..	..	..	..	..	..	..	..	..	..
22	2·3	1·6	·7	..	..	..	1·3	·6	..	..	..	..	·3	..	..	..	..
24	2·6	2·3	1·3	·6	..	..	1·8	1·1	..	..	..	..	·9	..	..	..	..
26	3·0	2·7	1·8	1·2	·3	..	2·2	1·6	·5	..	..	..	1·3	..	..	..	..
28	3·3	3·2	2·2	1·7	·8	·3	2·5	2·0	1·0	·1	..	..	1·6	·5	..	..	..
30	3·6	3·5	2·6	2·2	1·4	1·0	2·9	2·4	1·5	·5	..	..	1·9	1·1	..	..	..
32	3·9	3·8	3·0	2·5	1·9	1·5	3·2	2·8	2·0	1·0	·4	..	2·2	1·4	·5	..	..
34	4·2	4·1	3·3	2·8	2·3	2·0	3·5	3·1	2·4	1·6	1·0	·2	2·4	1·7	1·1	..	..
36	4·5	..	..	..	..	..	3·8	3·5	2·7	2·0	1·4	·8	2·7	2·0	1·6	·2	..
38	4·7	..	..	..	..	..	4·1	3·8	3·0	2·3	1·7	1·2	2·9	2·3	1·9	·8	..
40	5·0	..	..	..	..	..	4·3	4·1	3·4	2·6	2·0	1·6	3·1	2·7	2·3	1·5	·7
42	..	..	..	..	..	..	..	..	..	3·0	2·2	..	3·4	2·9	2·5	1·7	·9
44	..	..	..	..	..	..	..	..	..	3·3	2·3	..	3·6	3·2	2·7	2·0	1·3

Growth in Diameter (without bark) of Deodar saplings in a Plantation.

Age in years.	DIAMETER IN INCHES.											
	MAXIMUM. At a height of				AVERAGE. At a height of				MINIMUM. At a height of			
	1′	5′	15′	25′	1′	5′	15′	25′	1′	5′	15′	25′
4	·6	..	..	..	·1	..	..	..	..	..	..	..
6	1·1	..	..	..	·4	..	..	..	·2	..	..	..
8	1·5	·2	..	..	·7	..	..	..	·5	..	..	..
10	2·0	·7	..	..	1·0	·2	..	..	·7	..	..	..
12	2·3	1·2	..	..	1·3	·6	..	..	·9	..	..	..
14	2·7	1·6	..	..	1·6	·9	..	..	1·1	·3	..	..
16	3·0	2·0	·6	..	1·9	1·3	..	..	1·4	·6	..	..
18	3·3	2·4	1·1	..	2·3	1·6	..	..	1·6	1·0	..	..
20	3·6	2·8	1·7	..	2·6	2·0	·7	..	1·9	1·5	..	..
22	3·9	3·1	2·1	·2	2·8	2·3	1·1	..	2·2	1·8	..	..
24	4·2	3·4	2·5	·7	3·0	2·5	1·4	..	2·5	2·1	·4	..
26	4·4	3·8	2·9	1·1	3·2	2·7	1·7	..	2·8	2·4	1·0	..
28	4·6	4·0	3·2	1·5	3·4	2·9	2·0	·3	3·0	2·6	1·4	..
30	4·9	4·3	3·5	1·8	3·6	3·1	2·3	1·0	3·2	2·8	1·8	..
32	5·1	4·6	3·8	..	3·8	3·3	2·5	1·3	3·4	3·0	2·1	..
34	5·4	4·8	4·0	..	4·0	3·5	2·7	1·6	3·6	3·2	2·4	.4
36	5·6	5·0	4·2	..	4·1	3·7	3·0	1·9	3·8	..	..	·9
38	5·8	5·2	..	..	..	3·9	3·2	2·2	4·0	..	..	1·3
40	6·0	5·4	·	..	..	4·1	3·4	2·5	4·1	..	..	1·6

(*v*) *Volume Increment of Deodar saplings.*
(cubic feet).

Age (years).	Plantation.			Natural.			Age (years).
	Maximum.	Mean.	Minimum.	Maximum.	Mean.	Minimum.	
15	·18	·10	..	..	..	..	15
16	·24	·13	..	..	..	..	16
17	·31	·16	..	..	..	..	17
18	·38	·19	..	..	..	..	18
19	·46	·23	..	..	..	..	19
20	·54	·27	·08	·18	·06	..	20
21	·63	·32	·10	·22	·10	..	21
22	·72	·37	·13	·30	·14	..	22
23	·82	·42	·16	·38	·18	..	23
24	·92	·47	·20	·47	·22	..	24
25	1·02	·53	·24	·56	·26	·06	25
26	1·13	·61	·29	·67	·31	·07	26
27	1·25	·69	·35	·78	·38	·09	27
28	1·38	·77	·41	·90	·46	·12	28
29	1·52	·86	·48	1·06	·55	·15	29
30	1·67	·95	·55	1·26	·65	·18	30
31	1·83	1·04	·62	1·46	·75	·22	31
32	2·00	1·13	·69	1·67	·86	·27	32
33	2·18	1·22	·77	1·88	·97	·33	33
34	2·38	1·31	·85	2·12	1·08	·40	34
35	2·60	1·41	·93	2·40	1·19	·47	35
36	..	1·52	1·02	2·68	1·31	·54	36
37	..	1·63	1·11	..	1·43	·62	37
38	..	1·75	1·20	..	1·56	·70	38
39	..	1·87	1·30	..	1·69	·79	39
40	..	2·00	1·40	..	1·73	·89	40
						1·00	41
						1·12	42
						1·24	43
						1·37	44
						1·50	45

Volume calculated by πr^2 method.

SPECIES—*CEDRUS DEODARA.*

EFFECT OF THINNINGS.

Some sample plots laid out to test the effect of thinning were remeasured.

The first pair were laid out in Dartrund forest, Chamba State, Punjab, by Mr. Lace in 1899, Aspect E., Elevation 7,000 feet, Slope 25° to 30°, Age in 1899—87 years, Height about 84 feet. Open to grazing.

UNTHINNED PLOT.			THINNED PLOT.		
AREA ON THE SLOPE 1 ACRE.			AREA ON THE SLOPE 1 ACRE.		
	No. of trees.	Sectional area (sq. ft.).		No. of trees.	Sectional area (sq. ft.).
June 1899 . .	141	252·9	Originally . .	153	237·7
May 1915 . .	131	282·1	After thinning—		
			June 1899 .	73	136·1
			May 1915 .	59	164·4

The unthinned plot shows a difference of *29·2 square feet* or *11·5 per cent.* increase in 16 years.

The thinned plot shows a difference of *28·3 square feet* or *21 per cent.* increase in 16 years.

The actual increment in both plots is thus much the same, but in the thinned plots it is put on to fewer trees.

The second pair were laid out in Gothan forest, Chamba State, by Mr. Lace, also in 1899.

Aspect N.N.W. Elevation 6,300 feet, Slope 25° to 30°, Age in 1899—90 years. Height 90 feet, Soil heavy clay. Closed to grazing.

UNTHINNED PLOT.			THINNED PLOT.		
AREA ON THE SLOPE $\frac{2}{3}$ ACRE			AREA ON THE SLOPE $\frac{2}{3}$ ACRE.		
	No. of trees.	Sectional area (sq. ft.).		No. of trees.	Sectional area. (sq. ft.).
October 1899 .	92	136·9	Originally .	129	..
July 1912 . .	84	162·9	After thinning—		
			October 1899 .	81	99·3
			July 1912 . .	77	118·7

The unthinned plot shows a difference of *26 square feet* or *19 per cent.* increase in 13 years.

Thinned plot shows a difference of *19·4 square feet* or *19 per cent.* increase in 13 years.

The actual increment in this case is less in the thinned plot ; and as the percentage of increase is the same in both plots, thinning seems not to have affected the rate of growth of individual trees.

The third pair were laid out in Gothan forest by Mr. McIntyre in 1894. Aspect N.W., Elevation about 7,000 feet, Slope 20°, Age in 1894—90 years, Height 85 feet. Soil clay. Closed to grazing since 1885.

UNTHINNED PLOT.			THINNED PLOT.		
AREA ON THE SLOPE ·63 ACRE.			AREA ON THE SLOPE ·63 ACRE.		
	No. of trees.	Sectional area (sq. ft.)		No. of trees.	Sectional area. (sq. ft.)
1894 . . .	140	175·8	Originally . .	128	..
1899 . . .	141	162·9	After thinning—		
1912 . . .	137	190·4	1894 . .	98	148·6
			1899 . .	69	104·4
			1912 . .	67	124·7

The unthinned plot shows a difference of *27·5 square feet* or *17 per cent.* increase in 13 years.

The thinned plot shows a difference of *20·3 square feet* or *19 per cent.* increase in 13 years.

The actual increment is again less in the thinned plot, but the individual trees have grown rather more rapidly as the percentage of increase is greater than in the thinned plot.

The absence of any marked stimulus to growth suggests that when thinning has been deferred to so advanced an age as 90 years, the utility of the operation is open to considerable doubt.

Stem analysis of a Tsuga Brunoniana *tree in Ramam forest, Singalila Range, Darjeeling Division, growing on a well-drained spur. Soil—loam. Undergrowth.*—Arundinaria racemosa *bamboo. Elevation, 8,500 feet. Age, 52 years. Total height, 67 feet. Girth at b.-h., 58 inches.*

(Data collected by the Forest Research Institute.)

Age (years).	Height (feet).	DIAMETER (INCHES) AT A HEIGHT OF								*Volume (cub. ft.).
		1′	5′	15′	25′	35′	45′	55′	60′	
5	1	..	..	..	..	..	..	..	..	..
10	6	·5	·5	..	..	..	..	..	..	..
15	13	2·2	2·3	..	..	..	..	..	..	·3
20	20	4·3	4·3	1·7	..	..	..	..	..	1·2
25	27	6·5	6·2	3·9	·8	..	..	..	..	2·9
30	34	8·7	7·9	5·8	2·5	..	..	..	..	5·6
35	41	12·0	10·1	8·8	5·0	2·5	..	..	..	11·4
40	48	15·3	12·6	11·5	8·1	5·4	1·4	..	..	21·1
45	55	17·8	14·2	13·0	10·2	8·0	3·7	..	..	30·3
50	63	20·4	16·2	14·2	12·2	9·6	6·1	2·4	·8	40·7
55	71	..	..	..	..	..	..	..	..	47·0

* Volume calculated by πr^2 method.

INDIAN FOREST RECORDS

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Note on the preparation of Turpentine, Rosin and Gum, from *Boswellia serrata* (Roxb.) gum-oleo-resin.

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INTRODUCTION.

This enquiry was started as part of a general enquiry into Indian Gums and Resins in 1908, but was not actively prosecuted until 1912, when both laboratory and tapping experiments were inaugurated.

The Chemical side of the enquiry was, from the first, carried out under considerable difficulties, owing to the absence of a suitable solvent still, and on this account the data obtained as to the cost of working still remains to be verified in an experimental factory.

No detailed information is given regarding suitable localities in which such an industry might be started, though from the statements of outturn such localities are indicated and further information on the subject can be obtained, either from the Local Officers or from the Forest Research Institute, Dehra Dun.

Throughout the enquiry Professor Wyndham Dunstan, F.R.S., Director of the Imperial Institute, London, has rendered great assistance in indicating market requirements by carrying out analyses, and by obtaining valuations on samples submitted to him from time to time.

The opportunity is here taken to acknowledge the help rendered by His Highness the Maharaja Scindia of Gwalior and his Conservator of Forests, Rai Bahadur Har Sarup, in allowing the Forest Economist to visit the State forests to see the tapping operations, and in supplying samples of the gum-oleo-resin. Thanks are also due to Messrs. Billson, Hill, Napier, Bartlett, Dunbar-Brander, Benskin, Starte, Bhadbhade and Patel for the assistance they gave in carrying out tapping experiments.

Part I.—General.

1. *Records dealing with the gum-oleo-resin of* Boswellia serrata.—Gamble in his 'Manual of Indian Timbers' states that when the bark of *Bosewellia serrata* is wounded it exudes a green gum-resin, which gives an agreeable scent when burnt. Watt in his 'Dictionary of the Economic Products of India,' page 515, Volume I, describes the gum-resin as a transparent golden-yellow semifluid substance, which slowly hardens with time. It is stated as being pungent, having a slightly aromatic taste and balsamic resinous odour.

2. *Uses as recorded in the past.*—It is stated by Gamble to be a kind of frankincense and to be used medicinally as a diaphoretic and astringent and to make ointment for sores. Watt states that it is a sweet-scented gum burnt in religious ceremonies and sometimes used to strengthen lime. The same author quoting Dr. Irvine states that "Gundabirosa" is the prepared gum-oleo-resin and is similar in appearance and quality to Venice turpentine. An oil distilled from it is said to be used medicinally. The gum-resin is also made into ointment. Rai Bahadur Har Sarup, late Conservator of Forests, Gwalior, states that this gum-oleo-resin after being prepared by boiling and filtering is used in the local textile industry for calico-printing.

3. *Basis of enquiry.*—In 1908, Mr. R. S. Troup, Forest Economist, started an enquiry into gums, resins and oleo-resins obtained from Indian trees, with a view to selecting a few of them for special enquiry after information of a general character had been collected as to the amount of raw material available. The collection of such information took time, and it was not until about 1912 that it was found possible to make a selection, of which *Boswellia serrata* gum-oleo-resin showed by far the greatest promise. The enquiry naturally falls under two distinct headings: the one relating to distribution of the species, method of tapping, outturn, value and cost of production; and the other, the chemical side, which deals with the separation of the gum, turpentine and rosin, the analysis of the same and the necessary plant.

Part II.—Distribution, method of tapping, effect of tapping, cost of extraction and outturn.

1. Distribution.

Boswellia serrata is found widely distributed throughout the dry zone forests. It is found from the Sutlej extending eastwards to Nepal, on the outer slopes of the Umballa and Saharanpur Siwaliks. It is common throughout Rajputana, Bihar and Orissa, in the Circars,

the Central Provinces, Khandesh, especially on the slopes of the Satpuras, in the Deccan and Carnatic, but not found in Assam or Burma. The tree often forms the major part of the crop on hot rocky hill sides, and is often the forerunner of better forests as soon as protection from fire and grazing is introduced. A good deal of information has been collected from certain localities as to the number of trees available for tapping, the figures in most instances being based on Working Plan valuations and reports from local officers. Though it will be seen from the following figures that the number of trees is very large, they only represent those in selected areas, about which information has been collected.

Name of Division.	Locality or name of Reserve.	Number of *Boswellia serrata* trees available for tapping.	REMARKS.
BOMBAY PRESIDENCY.			
East Khandesh	1. Chopda Range	11,56,507	
	2. Yaval "	8,10,128	
	3. Raver "	8,46,670	
West Khandesh	1. Deomogra Reserve. Blocks I and II and Ashta Round.	2,10,000	
	2. Navapur Reserve	21,48,195	
	3. Pimpalner Reserve.	3,17,000	
	4. Sakri Range	Plentiful. No. not known.	
North Khandesh	Shirpur Range	61,34,410	
Panch Mahals	The North of the Godhra Range, in East of the Kalol Range, South of the Halol Range and in the Jhalod forests of the Eastern Mahals.	A fair number of trees available for tapping.	
CENTRAL PROVINCES.			
Hoshangabad	....	The species is common and the potential outturn of gum-oleo-resin is large.	
Chhindwara	Amarwara Range	Common.	
	Sillewani "		
	Sank "		
	Ambara "		
	Umreth "		
Narsinghpur	....	Common throughout the forests, though the number of trees of over 3½′ girth is estimated at only 6,650.	

Name of Division.	Locality or name of Reserve.	Number of *Boswellia serrata* trees available for tapping.	REMARKS.
CENTRAL PROVINCES—*contd.*			
Balaghat	Baihar Range	700	
	Sonawani ,,	600	
	Lanji ,,	2,159	
	Paraswara ,,	1,000	
	Dhansua ,,	1,000	
Bhandara	Bawanthari Range	18,828	
	Gaikhuri ,,	5,740	
	Partabgarh ,,	8,363	
Bilaspur	Sonakhan Range	Moderately common, total number of trees over 3½′ girth estimated to be 2,400.	
	West Lormi ,,		
	East Lormi ,,		
	Pantora ,,		
North Chanda	Moharli Range	Common, trees over 3½′ girth estimated at 5,472.	
	Haveli ,,		
	Warora ,,		
	Brahmapuri ,,		
Nagpur-Wardha	East Pench Range	9,072,162	
	West Pench ,,	2,486,220	
North Raipur	Whole Division	26,635	
South Raipur	Balod Range	41,721	
	Dhamtari ,,	30,402	
	Singpur ,,	40,130	
	N. Sihawa Forest	24,331	
		Trees over 24″ girth :—	
* Nimar	Khandwa Range	1,298,283	
	Punasa ,,	49,031	
	Chandgarh ,,	44,063	
	Singaji ,,	15,374	
	Kalibhit ,,	45,372	
	Piplod ,,	45,136	
	Chandni ,,	5,041,953	
	Burhanpur ,,	3,508,407	
		Trees over 2½′ girth :—	
* Melghat	Dhulghat Range	400,000	
	Gulamal ,,	200,000	

* NOTE.—The Conservator of Forests, Berar Circle, in forwarding the reports from the D. F. O.s. expresses the opinion that the estimates are high and should be treated with caution.

Name of Division.	Locality or name of Reserve.	Number of *Boswellia serrata* trees available for tapping.	REMARKS.
		Trees over 2½′ girth :—	
* Yeotmal	Yeotma Range	14,648	
	Darwha ,,	23,092	
	Pusad ,,	216,142	
	Kinwat ,,	366,468	
	Kelapur ,,	255,000	
	Wum ,,	9,316	
MADRAS PRESIDENCY.			
North Coimbatore	Gutialatur Range Talamalai ,, South Bargur ,, North Bargur ,,	Occur over 10,000 acres, 1 to 10 trees per acre.	
South Vellore	Polur Range.	Found in fairly large quantities.	
South Salem	Salem, East Range Harur, North ,,	Relatively small quantities available for tapping.	
Bellary	Sandur leased forests	120,000	The Conservator states that it is probably more widely distributed than has been reported.
Chittoor.	Vayalpad Range	10,000	No local use made of the gum-oleo-resin.
Nellore	Nandavaram A and B Blocks	Scattered in the forests, over 2,824 acres.	
East Cuddapah	Seshachellam Reserve.	Scattered in the forests, not found in large quantities.	

It must be clearly understood that the above figures represent only a very rough estimate of the number of trees available for tapping, and also that the species occurs in many other localities, though most commonly in those mentioned.

2. METHOD OF TAPPING.

(*i*) *Nimar Experiments.*

A good deal of difficulty has been experienced in ascertaining the best method of tapping *Boswellia*, which has necessitated a series of experiments being carried out, not only in widely separated areas but at different times of the year, as the season of tapping has a marked effect on the yield. Moreover, as little was known about the tapping of this tree when the enquiry was first taken in hand, a number of different methods were tried, most of which gave poor results. Preliminary experiments were undertaken in the Siwalik Division, United Provinces, and in the Melghat Division, Central Provinces, the results of which were sufficiently encouraging to justify more detailed experiments being carried out in the Nimar Division, Central Provinces. It was, therefore, decided to send the Assistant Forest Economist, Mr. E. Benskin, to Nimar, for this purpose. The results of his experiments are summarized as follows :—

* NOTE.—The Conservator of Forests, Berar Circle, in forwarding the reports from the D. F. expresses the opinion that the estimates are high and should be treated with caution.

The experiment was carried out in the Kirgaon forests of the Khandwa Range during January and February 1914.

Six sample plots were chosen, of an aggregate area of 49·2 acres, containing 1,023 *Boswellia* trees, classed as under :—

Girth 24″ to 30″	375 trees	= 8 trees per acre
,, 30″ to 36″	331 ,,	= 7 ,, ,, ,,
,, 36″ and over . . .	317 ,,	= 6 ,, ,, ,,

The trees were tapped by shaving a girdle of bark off the tree, a foot broad to about half the thickness of the bark, and freshing at stated intervals. The yield after a month's tapping, *i.e.*, from the 21st January till the 23rd February, according to girth-classes, was as follows :—

	lbs.
375 trees of 24″ girth up to 30″	= 21·26
331 ,, ,, 30″ ,, ,, to 36″	= 27·88
317 ,, ,, 36″ ,, and over	= 37·80
TOTAL .	86·94

The yield according to girth-classes per acre, per working season of 5 months, would therefore be—

	lbs.
Trees of 24″ girth up to 30″	= 2·27
,, ,, 30″ ,, ,, 36″	= 2·95
,, ,, 36″ ,, and over	= 3·58
TOTAL .	8·80

During the first half of the operations the flow was small, increasing gradually after each " freshing," so that the estimate is probably below the mark. This point will be made clear when describing the North Khandesh experiments. In order to ascertain the correct period for " freshing " the wounds, in sample plots I and II freshing took place every 4th day, in III and IV every 6th day, and in V and VI every 8th day. The results calculated on the yield per hundred trees of each class for one month were as follows :—

	Girth 24″ to 30″.	Girth 30″ to 36″.	Girth over 36″.	TOTAL.
	lbs.	lbs.	lbs.	lbs.
Freshing every 4th day Sample Plot I	8·2	13·9	20·9	75·4
,, ,, II	5·8	11·1	15·5	
,, ,, 6th ,, ,, ,, III	3·8	6·3	8·6	43·5
,, ,, IV	5·1	6·6	13·1	
,, ,, 8th ,, ,, ,, V	4·6	7·8	8·9	40·0
,, ,, VI	6·0	3·7	9·0	

From the above statement it is clear that the collection of the gum-oleo-resin and "freshing" of the cuts should be carried out at least every fourth day.

It was also found that only 47 per cent. of the trees yielded in large quantities, so that probably when working on a large scale it will be found necessary to eliminate a fairly large proportion of the trees from the operations. Mr. Benskin also drew certain conclusions from observations while at work, which deserve consideration. He considers that, as a general rule, it will be found that the following trees yield no gum-oleo-resin :—

(1) A large number of healthy trees of small girth.
(2) Old trees with black bark.
(3) Dwarfed and suppressed trees.
(4) Trees with a short bole.

The following yield well :—

(1) All sound and vigorous trees of 30 inches girth and over.
(2) All trees attacked by borers or otherwise diseased.
(3) Generally all hollow trees.

As the tapping carried out during the hot weather in the Siwaliks had proved a failure, and that carried out in January and February in Nimar had given fair but not conclusive results, it was determined to carry out a further series of experiments during the rains, *i.e.*, during July and August. These experiments were conducted by Mr. A. Dunbar-Brander, Divisional Forest Officer, Nimar. Two lots of 50 trees were tapped, the first from the 1st to the 31st July 1916, the second from the 31st July to the 30th August 1916. The method of tapping was the same as that adopted in the previous experiments. The process of collecting and freshing was repeated every three days, making a total of ten collections and freshings per month. The first 50 trees yielded 15·6 lbs. and the second 50 trees yielded 23·6 lbs. or 5·0 and 7·6 oz. of gum-oleo-resin per tree per month. These results compare favourably with former results ; but, on the other hand, it was found that owing to absorption of water in the rains, the crude "drip" was difficult to deal with in the solvent stills, in which the gum is separated from the rosin and turpentine. Should it prove possible to overcome this difficulty, at no great expense, it would allow tapping to continue for a longer period of the year.

(*ii*) *Experiments in the Bombay Presidency.*

The Bombay Authorities having under consideration the possibility of starting the *Boswellia* industry instituted three sets of

tapping experiments, one in the North Nasik Division, another in the Panch Mahals, and a third in the North Khandesh Division ; the latter yielded by far the most important results as yet obtained, having been carried out over a period of 5 months, by a specially appointed Forester, under the direction of the Divisional Forest Officer, Mr. Starte.

The experiments were commenced in November 1916 and were completed in June 1917. In all other experiments, the duration of tapping was limited to one to three months, whereas in this set of experiments tapping was continued throughout the working season ; the experiments are, therefore, of sufficient interest to justify Mr. Starte's report being quoted in detail.

"(1) On November 28th 1916, two parallel experiments in *Boswellia* tapping were commenced near Sulia in the Shirpur East Range of the North Khandesh Forest Division.

"(2) In *Experiment A*, thirty trees in each of the following girth-classes, *viz.* :—

(*a*) 24 inches—30 inches

(*b*) 30 inches—36 inches

(*c*) 36 inches and over

were tapped in December at about 3 feet 6 inches from the ground, a strip of bark 1 foot broad being removed all round the stem and nearly as deep as the cambium. The bark just above the wounds of trees Nos. 1—15 in each girth-class was then gently hammered, while trees Nos. 16—30 in each girth-class were not bruised in this manner. The trees were then left till the end of May 1917, when the tapping wounds were freshed every 5th day until the end of July when the experiment was stopped, as the yield of gum-oleo-resin was poor and rain washed away a certain amount of the drip which had exuded. It was originally proposed to re-bruise the bark of trees Nos. 1—15 just above the wounds at the time of each freshing, but as from Experiment B (see below) it had already been observed that this was worse than useless, resulting in a decrease of flow of gum-oleo-resin, none of the trees in this experiment were rebruised.

" (3) Details of the gum-oleo-resin collected from the trees in Experiment A are given below :—

Girth of trees.	Serial No. of trees.	NET QUANTITY OF GUM COLLECTED, IN OZ.		Total collection, in oz.	Average total collected per tree, in oz.	REMARKS.
		June.	July.			
24″ to 30″ .	1 to 15	3·2	12·4	15·6	1·04	Originally bruised.
Do. .	16 to 30	2·4	9·6	12·0	0·80	Not bruised.
30″ to 36″ .	1 to 15	2·0	12·4	14·4	0·96	Originally bruised.
Do. .	16 to 30	3·6	18·4	22·0	1·46	Not bruised.
Above 36″ .	1 to 15	4·0	11·6	15·6	1·04	Originally bruised.
Do. .	16 to 30	5·6	11·2	16·8	1·12	Not bruised.
TOTAL IN OZ. .		20·8	75·6	96·4	Average. 1·07	
No. of collections . .		5	4	9	..	

Thus the average total yield of gum-oleo-resin per tree was 1·07 or per collection $\frac{1 \cdot 07}{9} = 0 \cdot 12$ oz.

" (4) In *Experiment B*, thirty trees were tapped in December in each of the three girth-classes, as in Experiment A, and the drip was collected and the wounds were freshed approximately every 5th day, until the end of the June 1917, when the experiment was stopped. The freshing consisted of removing a *thin* layer of bark from the *upper half* of the wound, and by removing a further ½ inch or so of the bark from above the old wound. At the same time, throughout the experiment, the bark above the freshed wounds of trees Nos. 1—15 in each girth-class was bruised by gentle hammering.

" (5) Details of the gum-oleo-resin collected from the trees in Experiment B are given below :—

Girth of trees.	Serial No. of trees.	NET QUANTITY OF GUM COLLECTED.							Total collection, in oz.	Average total collected per tree, in oz.	REMARKS.
		December 1916.	January 1917.	February 1917.	March 1917.	April 1917.	May 1917.	June 1917.			
		oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	
24″ to 30″ .	1 to 15	14·0	14·8	24·0	22·4	23·2	40·4	2·8	141·6	9·4	Bruised at each freshing.
Do. .	16 to 30	33·6	30·0	50·4	67·6	46·4	41·2	5·6	274·8	18·3	Not bruised.
30″ to 36″ .	1 to 15	17·2	16·0	20·0	38·8	22·8	20·0	4·0	138·8	9·25	Bruised.
Do. .	16 to 30	38·4	64·0	63·2	57·6	69·6	53·6	15·2	361·6	24·1	Not bruised.
Above 36″.	1 to 15	43·6	58·8	40·0	50·0	44·4	67·6	5·6	310·0	20·7	Bruised.
Do.	16 to 30	129·6	138·0	171·2	209·6	140·4	169·2	21·6	979·6	65·3	Not bruised.
TOTAL IN OZ.		276·4	321·6	368·8	446·0	346·8	392·0	54·8	2206·4	Avrg. 24·5	

" (6) It will be observed that the bruised trees (Nos. 1—15 in each girth-class) yield much less drip than the unbruised trees (Nos. 16—30), and that the larger the girth the greater the yield. Again, it will be noticed that continued tapping increases the flow which reaches its maximum somewhere about the 20th time of freshing. This does not agree with the results obtained in Gwalior, where it is said that after the 4th " freshing " the yield remains practically constant.

" From the table it will also be seen that the average total yield of an unbruised tree over 36 inches in girth was 65·3 oz. or per collection 1·5 oz.

" (7) From both Experiments A and B, it will be seen that collections in June are very poor. This may be due to physiological reasons due to the change of season but it is also, to a certain extent, due to the mechanical washing away by rain of the gum-oleo-resin which had exuded. In any case, the rainy season is not suitable for collection of the drip as it is then difficult to move about in the forests ; and forest labour is not available, as high wages are paid to agricultural labourers at that season.

" (8) It has been noticed that thick-barked trees yield more gum-oleo-resin than thin-barked trees and that there is a marked exudation from cracks which occur in the bark of the

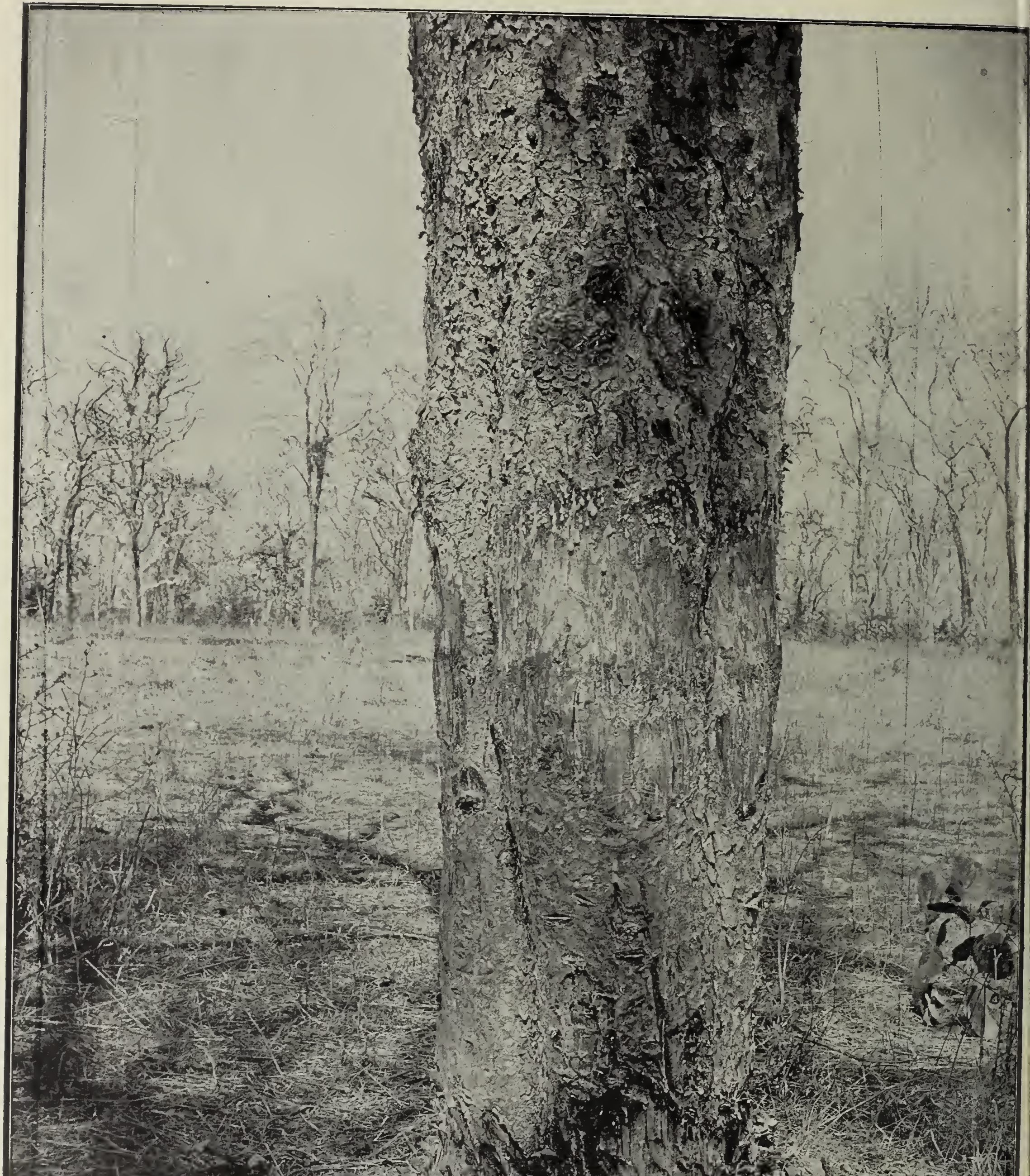


Photo. Mechl.-Dept., Thomason College, Roorkee.

Photo by R. S. Pearson.

Method of tapping *Boswellia serrata.*

Note heavy exudation on left side of stem.

[*To face page 11*

tapping * 'wound.' Large trees yield much more drip per square inch of wound than small trees, and it is therefore doubtful whether it will pay to tap small trees. There is apparently no extra yield from the south side of the tapped trees.

" (9) The tapping is done with 12 inches Draw-knives or Spoke-shaves, as they are found to be much handier than axes; and the gum-oleo-resin is scraped off the surface of the wound with blunt knives about 6 inches long.

" (10) A tapping wound one foot broad is apparently too large. The original wound might be made only 6 inches broad; and in freshing it, an inch or so might be left untouched at the bottom, and the wound should be started low down on the tree so as to allow for subsequent freshing above."

(*iii*) *Tapping in Gwalior State.*

Probably the most conclusive proof that tapping can be carried out on a commercial scale comes from the Gwalior State. In the Sheopur Range, some hundred miles from Gwalior city, tapping operations have been carried on, for generations, by the forest villagers of Sieroni, contracts having been given annually for the right of collection. When the writer inspected these forests in February 1917, he found that practically not a tree was to be found, large or small, which did not show marks of healed wounds. Plate I illustrates the result of tapping and the mode of healing of wounds.

The tapping is carried out by an aboriginal tribe, called "Saharyas," who work in pairs, generally two men or a man and a woman, the former blazing and the latter collecting the gum-oleo-resin. They estimate that one pair can collect 10 to 12 maunds per season, and this is probably about correct, when taking into consideration the price at which it is sold and the lazy habits of these people. The method of tapping is as follows :—

A blaze is made all round the tree, about 4 feet from the ground —it might, with advantage, be started lower down the stem—and to the depth of one-third the thickness of the bark. The blaze is made with a special instrument (Plate II), the head being of iron, some 6 inches long and 2 inches broad, slightly curved and with the cutting edge on the lower side, one end being fitted with an eye, to which a handle is fixed very similar to that of an axe, though slightly bent at the upper end.

* NOTE.—These cracks form in a longitudinal direction, as the bark dries, over the surface of the stem where tapping has taken place.

This instrument appears to be especially well adapted for the purpose, for not only is the blaze made quickly and cleanly, but the set of the blade makes it difficult to cut too deeply into the bark.

There appears to be some trouble in storing the crude gum-oleo-resin in tins, as it is difficult to get out the sticky mass when once it has settled. It will probably be found best to collect it in collapsible wooden buckets of conical shape and four-sided.

The first blaze consists of a 4-inch band, put on towards the end of the rainy season, this being a preparatory operation which results in no flow of the gum-oleo-resin. About a month later, the blaze is freshed by cutting off a thin shaving of bark all round the stem, over half the depth of the old blaze and taking in 2 inches of new bark on the upper edge of the original wound. This results in the exudation of a small amount of gum-oleo-resin which is collected, and a similar freshing is made and so on at intervals of about a week until the end of March, when collection stops. It was not possible to carry out experiments or to obtain very definite information as to yield per tree. Collection was, however, made from 20 average trees, the wounds on which had been once freshed, which amounted to 10 oz.; again, collection from 20 average trees which had been twice freshed amounted to 28 oz. or nearly three times as much, while two abnormal trees, twice freshed yielded 22 oz. The " Saharayas " stated that a very good idea of the probable yield of individual trees can be obtained by observing the amount of moisture in the bark at the time of freshing, and that trees in years of heavy rainfall yield more than in dry years.

3. (*i*) EFFECT OF TAPPING ON THE TREE.

It is of the greatest importance that by tapping the *Boswellia* trees their vitality should not be permanently impaired or that it should result in killing the trees, not only in connection with the yield but for sylvicultural reasons, as this species is generally the forerunner and nurse of more valuable species in the poorer class forests of the Dry Zone. While carrying out the tapping experiments and during subsequent inspections, careful observations were made in order to ascertain to what extent tapping affected the trees.

The Conservator of Forests, Berar Circle, and the Divisional Forest Officer, Nimar, inspected the experimental areas in the Kirgaon Reserve of the Nimar Division, some two years after tapping had taken place. In one area, where the original tapping experiments had been carried out by preparing a band 4 feet broad, the Conservator pronounced the operation as very severe and that it had resulted in the bark developing

Scale. 1" = 5".
Gwalior Tapping axe.

[*To face page 12.*

[illegible]

Photo. Mechl.-Dept., Thomason College, Roorkee. Photo by R. S. Pearson.

Effect of tapping *Boswellia serrata* for many consecutive years.
Sheopur Forests, Gwalior State.

[*To face page* 1

longitudinal cracks, which in large trees had exposed the wood and caused serious damage.

In the case of the trees tapped by Mr. Benskin, in which only a narrow band was cut and freshed at intervals, the Conservator stated that the trees did not show such decided injuries, but from former observations he anticipated that the injury would develop after the second year. As a note of alarm had been sounded as to the effect of tapping on the trees, and with a view to ascertaining whether the damage only develops after the second year, as anticipated by the Conservator, the writer inspected the above-mentioned area three years after tapping had taken place. All tapped trees were inspected, counted and classified, with the result that 20 trees were found to be dead, 10 very hard hit and 993 had, for all intents and purposes, completely recovered, the wounds having healed up, the trees being in full leaf. Those trees that had died were old trees, in some cases faulty, in all cases smothered with *Loranthus* and severely attacked by insects. Whether tapping or insect attack had killed the trees it is not possible to say, as trees were found dead outside the tapping area, some of which were, and some not, attacked by insects.

In the case of the trees which had been tapped by the Divisional Forest Officer, Nimar, and on which a 4-feet broad band had been cut, the blazes had developed by cracking, and resulted in very severe wounds. Though many of the trees had recovered to a surprising extent, such drastic tapping is not advocated.

The most definite proof is available from Gwalior that no serious damage is done to the trees by tapping, provided the operation is confined to a 8 inches to 12 inches band and then freshed. In that locality, the trees had been tapped in this way year after year for generations, and not a single tree was found to have been killed. Plate III illustrates the average state of a tree, which has been subject for years to tapping and which, when photographed, was growing vigorously.

3. (*ii*) CONCLUSIONS BASED ON THE TAPPING EXPERIMENTS.

The conclusions arrived at from the experiments carried out in Nimar and Khandesh, as also from the corroborative evidence available from Gwalior, are that—

(*a*) The method of tapping should be by shaving off a thin band of bark some 6 inches broad, 2 feet to 2 feet 6 inches from the base of the tree.

(*b*) Tapping should generally be commenced in November and should stop before the break of the monsoon.

(*c*) Freshing should be undertaken every 4th or 5th day, and should consist in removing a thin shaving of $\frac{1}{2}$ inch to 1 inch of new bark from the upper edge of the original belt, and carrying down the freshing to within an inch of the lower edge.

(*d*) Tapping of trees below 30 inches in girth is not advocated.

(*e*) If, after the initial tapping and after the first freshing has taken place, individual trees yield little gum-oleo-resin, they should be excluded from the operations.

(*f*) The effect of tapping on the trees need cause no serious apprehension.

(*g*) Taking into consideration the number of trees available for tapping in certain localities, together with the yield per tree, the outturn is sufficient to justify the erection of a plant working on commercial lines.

4. COST OF EXTRACTION AND OUTTURN.

(*i*) *Cost of Extraction.*

To arrive at a definite figure of cost of extraction by carrying out experiments is not possible. Various estimates have been framed by the officers who have carried out some of the experiments, amongst which the following may be cited :—

Mr. Benskin sees no reason why the gum-oleo-resin could not be collected at from 1 to $1\frac{1}{2}$ annas per lb. or Rs. 5 to Rs. 7-8 per maund.

Mr. Starte found that a Bhil could collect the drip from, and fresh the wounds of, 50 trees per day ; assuming that they got 4 annas per day and only tapped trees of over 36 inches girth, then the cost in the forest per maund would be $\frac{4+80+40}{3\cdot1+50}$=Rs. 4-3 exclusive of royalty.*

Both the above estimates are based on knowledge gained while carrying out experiments, with unskilled labour and under entirely new conditions. In the Sheopur Range of Gwalior, where the labour is used to the work, the gum-oleo-resin was purchased by the Forest Department at Rs. 3 per maund, where labour is available at 3 annas a day, so that Mr. Starte's estimate where labour is paid 4 annas per day is probably somewhere near the mark. Were the tapping operations extended over large areas, there can be no doubt that though supervision would fall per unit and experience result in more economic methods of working, the price of collection would rise, if for no other reason than that the lead would be increased, so that probably somewhere about Rs. 5 per maund should be taken as the figure on which to base calculations of working.

* NOTE I.—By including all trees down to 30″ girth the cost of collection will be slightly increased.

(*ii*) *Outturn.*

In order to form an estimate of annual outturn, we have to take into consideration the number of trees available for tapping, the yield per tree and the rotation on which tapping can be carried out.

An approximate estimate has been given of the number of trees available in various localities, though no definite information is available as to how many trees fall into each girth-class, so that it will only be possible to base the calculation of outturn on the total number of trees available for tapping, multiplied by the average yield per tree from all sizes, and to divide that figure by the number of years of the fixed rotation.

The average yield per tree of over 24" in girth, as ascertained in the North Khandesh experiments, in the case of trees not bruised before freshing, was 35·9 oz.=2·25 lbs. per annum. It is not possible to make any definite statement as to the best rotation of tapping: in Gwalior, they tap every year and give the tree no rest; from inspections in Nimar, it was thought that better results could be obtained by giving the trees two years' rest, thus fixing the rotation at three years. Based on the above data, the following figures of annual yield have been arrived at:—

Name of Division.	Locality or name of Reserve.	Number of *Boswellia serrata* trees available for tapping.	Approximate annual yield available, in lbs.	REMARKS.
BOMBAY PRESIDENCY—				
East Khandesh	1. Chopda Range	11,56,507	8,67,380	
	2. Yaval ,,	8,10,123	6,07,596	
	3. Raver ,,	8,46,670	6,35,002	
		TOTAL	21,09,978	25,731 mds.
West Khandesh	1. Deomogra Reserve	2,10,000	1,57,500	
	2. Navapur ,,	21,48,195	16,11,146	
	3. Pimpalner ,,	3,17,000	2,37,750	
		TOTAL	20,06,396	24,468 mds.
North Khandesh	Shirpur Range	61,84,410	46,38,307	56,565 mds.
Panch Mahals	....	Number not known, probably not large.	..	
CENTRAL PROVINCES—				
Hoshangabad	....	Number not known.	Potential outturn large.	
Chhindwara	....	Number not known.	Fairly large.	

Name of Division.	Locality or name of Reserve.	Number of *Boswellia serrata* trees available for tapping.	Approximate annual yield available, in lbs.	Remarks.
Central Provinces—*contd.*				
*Narsinghpur . . .	....	6,650 over 42" girth.	8,867	Estimated on a 4 lbs. yield per tree.
*Balaghat . . .	Five Ranges . .	Trees over 3½" girth, 6,459	8,612	
*Bhandara . . .	Bawanthari Range .	..	..	
	Gaikhuri " .	32,931 over 42" girth.	43,908	Estimated on a 4 lbs. yield per tree.
	Pertabgarh " .	..	..	
*Bilaspur . . .	Four Ranges . .	Not commonly found over 42" girth.	..	
*North Chanda . .	Moharli Range .	..	..	Estimated on a 4 lbs. yield per tree.
	Haveli " .	..	..	
	Warora " .	5,472	7,296	
	Brahmapuri " .	..	..	
Nagpur-Wardha . .	E. Pench " .	11,558,382	8,668,786	Probably a very high estimate, which requires further verification.
	W. Pench " .			
North Raipur . . .	Whole Division .	26,635	19,975	
South " . .	Balod Range .	136,584	102,438	
	Dhamtari " .			
	Singipur " .			
	N. Shawa Forests .			
Nimar	....	7,535,713	425,250	Trees over 24" girth calculation based on 2·25 lbs. yield per tree.
	Eight Ranges .	10,047,619	7,535,713	
Melghat	Two Ranges .	600,000	450,000	
Yeotmal . . .	Six Ranges .	884,666	663,498	Ditto
Madras Presidency.				
North Coimbatore . .	Gutialatur . .	50,000	37,500	Ditto.
	Talamalai . .			
	S. Bargur . .			
	N. Bargur . .			
South Vellore . .	Polur Range . .	Found in fairly large quantities in Polur Range.	..	
South Salem . . .	Salem, E. Range .	Small quantities available.	..	
	Harur, N. " .			
Bellary	Sandur leased forests	1,20,000	90,000	
Chittoor	Vayalpad Range .	10,000	..	
Nellore	Nandavaram A. and B. Blocks.	Not available in large quantities.	..	
East Cuddapah .	Seshachellam Reserve.	Not available in large quantities.	..	

* Note II :—The reports from local Forest Officers deal only with trees of over 42" girth and therefore eliminate large numbers of trees suitable for tapping. It follows that the yield shown in column 4 is far below that available.

In the Bombay Presidency, the most suitable localities for such an industry will probably be found in the Shirpur Range of the North Khandesh Division, in the Chopda, Yaval and Raver Ranges of the East Khandesh and in Navapur Range of the West Khandesh Divisions. Though no definite information is available from the Hoshangabad Division of the Central Provinces, it is understood that supplies from that locality are considerable, and that the same may be said of Nimar and Nagpur-Wardha, though in those Divisions labour may be a difficulty. In Madras, the Conservator is of opinion that the trees are found in even greater quantities than is reported by the local officers.

Part III.—Chemical Analysis.

1. CHEMISTRY OF THE GUM-OLEO-RESIN.

This gum-oleo-resin has been known for a long time under the familiar name of *olibanum.* Its chemical composition has been the subject of detailed investigation in connection with several African species of *Boswellia* by Tschirch and Halbey.[1] *Boswellia* oil has been investigated by Stenhouse, Lowing, Kurbatow, Wallach Rheindorff, Walter and in the Laboratories of Messrs. Schimmel & Co.; the latter discovered the presence of Dipentene and Phellandrane.[2]

In addition to lævo pinene already found to constitute the main bulk of the oil, *Boswellia* resin consists of Boswellic acid $C_{32} H_{52} O_4$, free and combined as an ester with oliban-resenes $(C_{14} H_{22} O)_3$. The gum is stated to consist of arabic-acid, bassorin and a bitter principle. The following is the composition of the *olibanum,* as given by Tschirch[3] :—

	Per cent.
Oleo-resin (including 0·5 per cent. undetermined bitter principle) extracted by 90 per cent. alcohol	72
Gum	20
Bassorin	6–8
Plant remains	2–4

A sample of the Indian *Boswellia serrata* gum-oleo-resin was examined at the Imperial Institute, London, the report on which is given in the

[1] Uber das olibanum Arch. d. Pharm 1898 S. 487. Details in der Dissertation, Halbeys, Bern 1898.

[2] Die, Harze and die Harz behalter von A. Tschirch pp. 411 et 415.

[3] Tschirch *loc. cit.* and Dr. Karl Dietrich Analysis of Resins, Balsams and Gum-resins, p. 328 ; also Southall's Materia Medica by Barclay, p. 244.

Technical Reports and Scientific papers of 1903, page 162, from which the following extract may appropriately be given here :—

"The sample supplied consists of small rounded tears and larger irregular masses. The tears were yellowish in colour, opaque and brittle, breaking with irregular waxy fracture, the masses were light brown in colour, opaque and much softer than the tears. The odour and taste were strongly terebinthinous. The gum-resin readily burned giving off its characteristic aromatic odour.

"Its chemical composition was found to be as follows :—

	Per cent.
Resin	33·2
Gum	36·45
Volatile oil	7·0
Ash	1·55

"The gum was almost completely soluble in water, and the mucilage gave the ordinary reactions of gum-arabic.

"Owing to the small quantity of gum-resin supplied, the amount of the volatile oil obtained was insufficient for a complete examination. The greater portion boiled at 157°C., after which the temperature rose to over 170°C., but the quantity of liquid left was too small to continue the experiment.

"Previous analyses of frankincense have been published by Braconnot (Annales de Chemie, (2) 68, 60) and Kurbatow (Zeitschrift fur Chemie, (2) 7, 201).

"Braconnot found—resin 56 per cent., soluble gum 30 per cent., insoluble gum 6 per cent. and volatile oil 8 per cent. Kurbatow gives the following figures—resin 72 per cent., gum 21 per cent., volatile oil 7 per cent. He also separated the volatile oil into a terpene boiling at 156-158°C. Wallach has recently examined the oil from true frankincense and has shown that olibene is identical with lævo pinene, and that dipentene is contained in the higher boiling fractions (Liebig's Annalen, 252;94). From a comparison of these analyses it will be seen that the gum-oleo-resin from *Boswellia serrata* is almost identical in chemical composition with that obtained from the other species of *Boswellia*, which forms the frankincense of commerce. There is,

> therefore, no apparent reason why this Indian gum-oleo-resin should not be used in place of the African or Arabic product. At the present time there is little demand for frankincense in this country, its chief use being as an ingredient of incense."

Again, when in 1911, the Forest Economist selected this gum-oleo-resin as a subject for further investigation on account of the common occurrence of *Boswellia serrata* in the Indian Forests, it occurred to the writers that by splitting it up into different products, there was a far better prospect of placing it in quantity on the market than by utilizing it as "olibanum" or "frankincense," and this impression was confirmed by the above-mentioned report published by the Imperial Institute. As occasion permitted, the work has been carried out during the last four years, and the samples prepared in the Laboratory of the Forest Research Institute were submitted to interested parties for commercial valuation and criticism. By this procedure, indications as to the class and grade of products required by the market have been obtained, thus guiding the writers in their work. In this connection, we would like to thank the Director of the Imperial Institute, whose reports and criticisms have been of the greatest assistance.

As the main object of the enquiry has been to develop a cheap commercial process by which the ingredients of *Boswellia serrata* gum-oleo-resin can be separated and to make samples for commercial valuation, it has not been considered necessary to verify the composition of *Boswellic* acid and other resins as already reported. On the other hand, the usual constants of the resin and oil were determined from time to time to arrive at standard constants for the Indian olibanum oil, while the composition of redistilled oil is under study. The major portion of this redistilled oil consists of Dextro-Pinene mixed probably with β—Pinene. Phellandrene is absent in this major fraction of the oil. The residue left after the distillation of Pinene was too small to admit of a detailed examination, but which will be carried out by distilling larger quantities of oil as opportunity offers, and the exact chemical differences between this oil and that of the African frankincense will be discussed in a separate note.

2. PRELIMINARY ANALYSIS.

The percentage composition of the samples of the *Boswellia* gum-oleo-resin received from the States of Gwalior and Kotah and other localities is given below. These samples, with one exception, are the results of very elementary methods of collection by forest tribes and do

not represent even average qualities resulting from collection under proper supervision :—

Table of results of analysis on Boswellia *gum-oleo-resin, received from Native States and other localities.*

Description.	Moisture per cent.	Ash per cent.	Oil per cent.	Resin per cent.	Gum per cent.	Insoluble impurities.
(1) *Boswellia serrata* gum-oleo-resin received from the Kotah State in 1911-12.	11·91	0·11	8·00	52·99	25·52	1·58
(2) *Boswellia serrata* gum-oleo-resin received from Gwalior State.	4·05	..	8·05	59·62	28·28	
(3) A dried sample from Gwalior State.	6·61	..	6·21	63·32	23·86	
(4) A fresh sample tapped personally by Mr. E. Benskin, Assistant Forest Economist.	6·26	..	9·14	57·97	26·63	

Sample No. 2 was also extracted by petroleum ether and other solvents on a large scale in the Laboratory extraction apparatus and the yield on an average was as below :—

	Petroleum ether.
Oil	7·50
Boswellia Rosin	55·50
Gum	33·10
Insolubles	3·90

The results of the analysis of samples collected by the Divisional Forest Officer, Khandesh, during 1917 are given below :—

Analysis of samples collected by careful tapping, under the supervision of the Forest Department.

Serial No.	Description.	Month of collection.	Moisture per cent.	Oil per cent.	*Bowellia* Rosin per cent.	Gums, Soluble in excess of water.	Insolubles, mostly consisting of woody matter, sand dust.
1	Tappings from hammered trees Nos. 1-15, girth 24″-30″.	February 1917.	11·45	7·61	57·12	17·30	6·52
2	Tappings from unhammered trees Nos. 1-15, girth above 36″.	March 1917.	13·82	9·60	52·75	19·55	4·28
3	Tappings from hammered trees Nos. 1-15 girth 30″-36″.	April 1917.	7·33	9·10	61·08	17·70	4·59
4	Tappings from hammered trees, Nos. 1-15, girth above 36″.	May 1917	11·72	9·23	55·84	16·62	6·59
5	Tappings from hammered trees, Nos. 1-15, girth 36″-36″.	June 1917.	15·17	7·89	60·82	10·03	6·09
6	Tappings from unhammered trees, Nos. 16-30, girth 30″-36″ (very wet, of the consistency of treacle).	June 1917.	22·60	5·04	51·49	10·36	10·51
7	Tappings from unhammered trees, Nos. 1-15, girth 24″-30″ (very wet, of the consistency of treacle).	July 1917.	24·68	5·84	52·91	10·40	6·17
8	Tappings from hammered trees, girth 24″-30″.	August 1917.	10·52	8·47	54·88	19·70	6·43

From the above results it is evident that collections should not be made during the rains, as the excess of moisture produces a peculiar treacle-like mass, which is the result of the gum swelling by absorption of water. Moreover, extraction is rendered difficult owing to the swollen wet gum forming a coating on the resin impermeable to solvents. An average sample of the gum-oleo-resin may thus be taken to be 10-11 per cent. moisture, 4-5 per cent. Insolubles, 8-9 per cent. oil, 55-57 per cent. *Boswellia* rosin, 20-23 per cent. of gum.

3. Constants of *Boswellia serrata* gum-oleo-resin.

(*i*) *Turpentine.*

The oil as distilled by steam on a large scale, at the Institute distillery, on redistillation and after eliminating all the fraction of high boiling residue, was examined with the following results :—

Bulk Fraction, Sp. Gr. @ 22°C.	0·8371	αD+32° 30′
High boiling Fraction, Sp. Gr. @ 22°C.	0·8675	αD+12° 12′

The fractional distillation of the original oil before rectification gave the following results, in an ordinary fractional distillation flask at Dehra Dun (Barometric pressure 27·8 inches) :—

	Per cent. (by volume)
Below 160°C.	50
160°–167°C.	17·5
167°–180°C.	11·0
Above 180°C.	22·5

The bulk fraction gave the following results :—

Below 155°C.	87
155°–160°C.	8
Above 160°C.	5

Residue left by the *Boswellia* turpentine on spontaneous evaporation after 3 months amounted to 0·8 per cent. as compared with 6·03 per cent. residue from the American and 8·42 per cent. from the French turpentine oils, the latter as obtained in the Indian markets, the oils having been allowed to evaporate under identical conditions.

From these results, it is evident that the constants of *Boswellia* turpentine closely resemble those of superior American and French turpentines. As already stated, this *Boswellia serrata* oil differs in some respects from the oil of African frankincense, consisting mainly of Dextropinene mixed with β-pinene.

The following are the results of examination of the rectified *Boswellia* turpentine oil as carried out by the Imperial Institute, London :—

"The oil on being examined at the Imperial Institute was found to have the following constants :—

Boswellia turpentine oil.		*Commercial turpentine oil.* American.	French.
Sp. Gr. at 15°C.	0·8446	0·858 to 0·877	0·865 to 0·875
Optical rotation αD	+31° 24′	—9° 30′ to 14° 17′ (rarely slightly lævo rotatory).	—29° to —33°
Ester value, before acetylation			2·6
Ester value, after acetylation			36·4

"On fractional distillation, the *Boswellia* oil gave the following results :—

Fraction boiling at—	Per cent.
153° to 160°C.	89
160° to 180°C.	11

"The fraction boiling at 153°C to 160°C was redistilled, and practically the whole passed over at 155°C.

"For comparison with these figures it may be stated that 85 per cent. of American turpentine oil usually distils between 155° and 165°C."

Constants of the oil obtained on a large scale by the use of petroleum benzine in the Forest Research Institute Laboratory gave the following constants :—

Sp. Gr. at 23-21°C.	0·8427
Flash point	77° Fah.
ND 23·5°C.	1·4575
αD	+21° 7·8′

Fraction.	By volume. Per cent.
Up to 155°C.	52
155°–160°C.	23
160°–167°C.	15
167°–170°C.	3·5
Residue above 170°C.	6·5

From these constants, it is evident that the oil, though refined by fractional steam distillation, still retains traces of petroleum benzine which affect its constants. The low flash-point is a disadvantage.

(*ii*) *Boswellia Rosin.*

The constants of *Boswellia* rosin were determined on two samples, which had been prepared in a model extractor, with either petroleum

ether or *Boswellia* turpentine as solvents. The results are as follows :—

——	Sample produced with *Boswellia* turpentine.	Sample produced with petroleum ether.
Sp. Gr. at 24°C.	1·058	..
Acid value (cold)	42·51	43·71
Saponification value	88·40	89·66
Iodine value (Hubl. 18 hours)	98·20	97·10

A bulk sample of *Boswellia* rosin prepared with petroleum benzine as a solvent, was sent to the Imperial Institute, London, for commercial valuation and determination of its constants with the following results :—

	Per cent.
Moisture	0·7
Ash	0·03
Melting point	68°C.
Acid value	55·1
Saponification value	90·2

(*iii*) *Gum.*

A sample of gum, completely freed from resin and insoluble woody matter was analysed and gave the following results :—

	Per cent.
Moisture, etc.	18·75
Ash	3·28
Water solubles in 5 parts of water	74·20
Water solubles (*i.e.*, the portion dissolved in 60 parts of water by repeated extraction)	74·35
Bassorin	7·05
Bassorin when using 60 parts of water	6·90

In order to form a fairly thick jelly, two parts of water have to be added to the gum, while by adding five parts of water a thin solution is obtained, and it is not until 50 parts of water are added that approximately complete filtration is possible.

The following are results of tests for comparative viscosity of the water solubles of *Boswellia* gum, gum arabic and gum tragacanth as

determined in a Engler's viscosometer :—

——	Moisture, etc. per cent.	Ash, per cent.	Strength of solution.	Time taken for the outflow of 200 cc. at 25°C.
				h. m. s.
(1) *Boswellia* gum . .	18·75	3·28	20 grams to 250 cc.	0 1 21
(2) Gum arabic . .	13·53	3·29	20 grams to 250 cc.	0 1 17
(3) Gum tragacanth .	19·91	2·87	10 grams to 1000 cc.	1 13 18
(4) Distilled water . .	..	..	..	0 0 52

Boswellia gum dissolved in 12·5 parts of water and filtered through cloth gave reactions similar to gum arabic, only the emulsion was slightly more opaque. The solution of soluble *Boswellia* gum as dissolved in 5 parts of water is more jelly-like than a similar solution of gum arabic.

Part IV.—Isolation of the three constituents of the gum-oleo-resin of *Boswellia serrata.*

The problem of separating the three products from each other has been the subject of prolonged enquiry, first on a laboratory scale and lately on a semi-commercial scale, the object of the latter being to prepare samples for valuation and at the same time to obtain first-hand evidence as to the most suitable type of plant.

The observations made in this chapter are based on actual experiments and record the difficulties actually met with.

1. Preliminary remarks.

From the nature of the three products, it is evident that the process of separating the products, from each other must necessarily be a mixed one, namely solvent-extraction and steam distillation. The separation of the gum from the oleo-resin is done by a solvent and the separation of the turpentine from the rosin by steam.

Steam distillation might answer the purpose if only oil and a residual mixture of the gum and resin were the products aimed at, or a solvent alone might suffice were the oleo-resin and the gum products required. From an industrial point of view, however, it is essential that all three products should be recovered in a high grade of purity. By steam distillation, it was found that the residue consisted of resin and gum in

the form of a well-churned emulsion. This emulsion offers many difficulties in subsequent separation, as the emulsion when evaporated becomes dark brown on exposure, due to the salts of tannin extracted from the woody chips and pieces of bark contained in the crude material. It is practically impossible to recover the gum in its original purity of colour and texture, unless it is treated in porcelain or enamelled ware and dried by a vacuum process, which is too costly to be adopted for the recovery of such a cheap material and even then the colour of the gum cannot be brought up to the natural hue. Again, the gum forms a coating over the resin which being impermeable to the usual solvents cannot be extracted with the help of any well-known solvent as easily as it is possible to do so in its original state.

It was, however, observed that by passing superheated steam over the crude material placed in a steam jacketed still, it was possible to distil the oil out without causing any injury to the texture of the gum, but by doing so the resin becomes fused by the superheated steam, runs out and sticks to the still, and can only be recovered with the help of a solvent. From what has been said above, the solution to the problem of separating the three products one from another resolves itself into either solvent extraction followed by steam distillation or steam distillation followed by solvent extraction.

2. SOLVENTS.

Before discussing the process adopted, it is necessary to consider, from a commercial point of view, the different solvents suitable for the extraction of the *Boswellia* resin. It has not been possible to try all the different solvents on a large scale, but as all of them have similar boiling points, any one of them may prove suitable according to the local conditions of work from the standpoint of comparative cost, loss during recovery and inflammability. It must be borne in mind that it has not been possible to determine the loss of solvent during recovery for want of proper plant at the Forest Research Institute, this being a very important point and for the same reason it has not been possible to try all the different solvents which may be suitable when working on a commercial scale. All that it has been possible to do is to carry out actual experiments on a large scale in the Institute distillery with only two solvents, *viz.*, petroleum benzine (boiling point up to 80°C) and alcohol. As regards the recovery, though it was not possible to work out figures at the Institute, the data available as to the loss of solvent during the extraction of fixed oils and fats from oil-seeds in factories working these products has been ascertained, and may be taken to represent a fair average figure. The modern extraction plant is so

well made that the loss of the solvent in a temperate climate is said not to exceed 0·5—1 per cent., and that even in India it is not expected to exceed 5 per cent. per 100 parts of the raw material : one firm working in India claims to work at a 2 per cent. loss only.

To keep down to this figure, however, condensation must be carefully attended to, and it is not advisable to attempt condensation with water at a higher temperature than 80°Fah., unless an unlimited supply of water is available, but even then the recovery of the solvent will take such an inordinate length of time that it is by no means certain that under Indian conditions, it would not be better to take the loss at say 5 per cent. instead of 2 per cent.

The *Boswellia* oleo-resin is soluble in all of the following solvents :—

(1) Alcohol (90 per cent., boiling point 78°C.)
(2) Ether anhydrous (boiling point 35°C.).
(3) Carbon-tetrachloride (boiling point 76°C.).
(4) Chloroform (boiling point 62°C.).
(5) Trichloroethylene (boiling point 88°C.).
(6) Petroleum ether (boiling point up to 60°C.).
(7) Petroleum benzine (boiling point 80°-110°C.).
(8) Acetone (boiling point 56°C.).
(9) Coal-Tar Naphtha (boiling point up to 110°C.).
(10) Benzol (boiling point 80°C.).
(11) Turpentine (boiling point 155°-160°C.).

Out of these Nos. (2), (3), (4), (6) and (10) are too costly to be considered for extraction on a commercial scale in this country. No. (5) is already used extensively for the extraction of oils, it is not inflammable and is recoverable to the extent of 98 per cent. in cold climates, like that of England and up to 95 per cent. in hot climates. Trichloroethylene appears to be an ideal solvent and its use is recommended for the extraction of *Boswellia* oleo-resin. Pre-war London prices were £45 per ton. Taking £46 per ton as the price of the solvent imported from England and delivered at the factory, it works out to annas 4-9 per pound or about Rs. 1-4 to extract one maund of resin, taking a maximum loss of 5 per cent. of the solvent during its recovery.

Acetone and alcohol are good solvents, but as they are miscible in water, their recovery is seriously affected by the admission of steam which is necessary for the full recovery of the solvent and, for this reason, the solvent chosen should be very volatile and immiscible with water. Alcohol dissolves the tannin and other colouring matter out of the woody chips and bark pieces contained in the crude material, which colours the residual gum light brown. The resin produced by alcoholic extraction is also a shade darker than that produced by petroleum benzine.

Petroleum benzine is an excellent solvent, and is generally used on a commercial scale in the extraction of oils and fats. It gives excellent resin of good colour and texture. Its cost is about annas 14 a gallon when purchased wholesale.

Mr. W. E. Fischer, a Chemical Engineer of London, was referred to as to the advisibility of using petroleum ether (boiling below 40°-70°C.) or petroleum benzine (boiling point up to 110°C.), and he recommends the use of the latter, with a good supply of cold water for the condensers, whose temperature he says should be below 75°-80°Fah. He further pointed out that even at this temperature of 80°F., a solvent like trichloroethylene (boiling point 88°C.) is difficult to condense, though the size of the condenser especially for work in tropical countries, is an important factor governing recovery.

Turpentine is the best solvent for the resin, and its recovery is assured, though it can only be used for extraction by maceration and as such large quantities are required, it has not been thought advisable to advocate its use here though, in a running concern, it might be employed for maceration with advantage.

Experiments have shown that the amount of solvent required when working by the Soxhlet process, is about three times the weight of the oleo-resin to be treated ; whereas when working according to the Maceration process by which the material has to be twice treated, as much as ten times the weight of the crude material is necessary.

Taking into consideration the advantages and disadvantages of the various solvents available, Petroleum Benzine is advocated, but as for the process to be employed with this solvent see below.

Trichlorethylene is the solvent also recommended.

Part V.—Proposed plant, method of extraction and preparation of the products for the market.

1. PLANT.

It must be clearly understood that the proposed plant, of which a rough design is given (Plate IV) is purely of an experimental nature, as owing to the tests carried out in the Forest Research Institute distillery having been made in an adapted still, certain factors remain undetermined.

The plant proposed for further experiments, which interested parties may care to carry out, is designed with a view to adopting it as a unit of a large-scale factory. Moreover, the design is far from being a complete working drawing, and is only intended as a guide to Engineering firms as to actual requirements.

It consists of a solvent extractor, and a steam-still, both fitted with Condensers ; two settling tanks, a solvent storage tank, turpentine solvent and resin receivers and a tank for collecting the "sludge." A small distillation plant is required to deal with the "sludge" which is not shown in the drawing.

The solvent extractor consists of a steam jacketted still, with a removable still-head, fitted with a double jacketted condenser, a worm condenser coil, safety valve and delivery pipe, leading to the main condenser. A removable perforated, tin-lined copper basket is supported on brackets in the still, and in this basket is fitted a spiral, perforated, steam coil, with a removable connection joint to the superheated steam in-let.

Below the solvent still are two large settling tanks with leads to the steam-still and "sludge-tank."

The Steam-still is an ordinary turpentine still, fitted with a removable still-head and steam jacket and with a perforated steam spiral coil at the bottom.

Both the solvent extractor and steam-still are provided with pressure gauges and thermometers ; while a pump, not shown in the drawing, is necessary to raise the solvent collected from the Steam-still to the Solvent-Storage-tank and a small redistillation plant connected to the "sludge-tank."

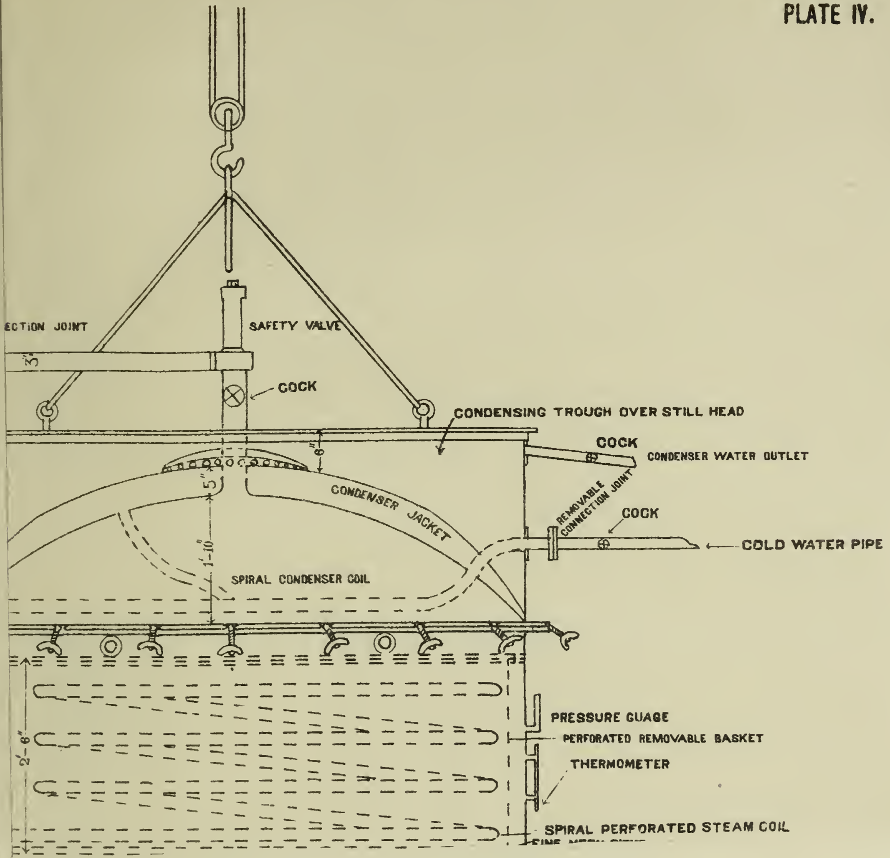
2. METHOD OF EXTRACTION.

Two methods of extraction are suggested, *i.e.*, either to use the solvent first and the steam afterwards, or to use superheated steam first and the solvent afterwards. In either case the same plant will be required, with this modification that in the former case the plant is as shown in the drawing, and in the latter the turpentine condenser will be above and the solvent condenser and storage tank will be on the ground.

(*i*) *Solvent extraction followed by steam distillation.*

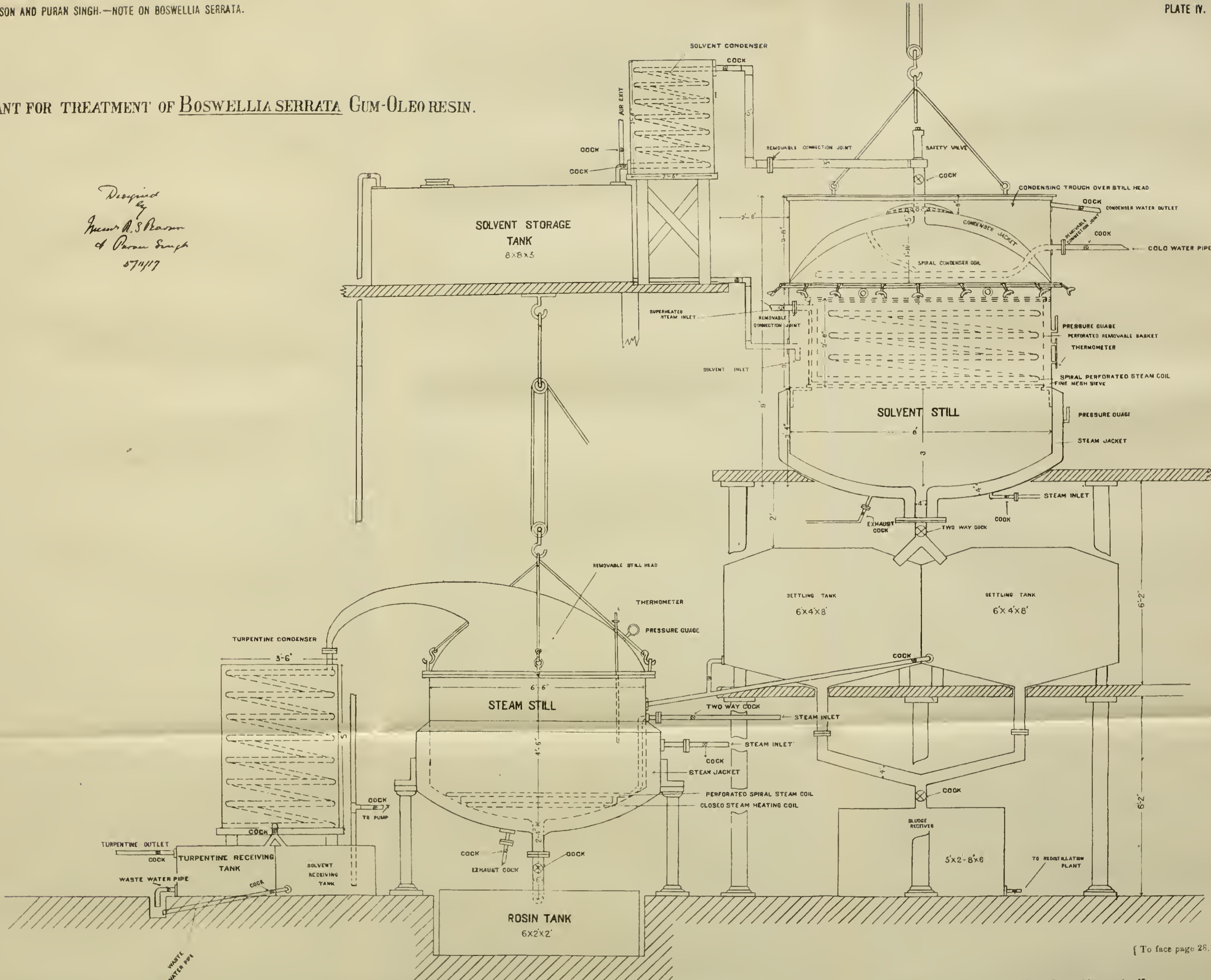
By this process, the gum-oleo-resin is first treated with a solvent which, in this case, should be trichloroethylene as it is easier to be driven out of the oleo-resin than petroleum benzine. The oleo-resin is dissolved out by the solvent, leaving the gum with woody impurities as residue in the extractor. The solution of oleo-resin is run into the settling tank, to free it of fine particles of dust and dirt, and on settling is decanted and run into the resin still for distillation at temperatures not exceeding 120°C.-130°C. The solvent is distilled off by gradually raising the temperature of the still with the help of the steam jacket.

PLATE IV.



ECTION JOINT
SAFETY VALVE
3"
COCK
CONDENSING TROUGH OVER STILL HEAD
6"
COCK
CONDENSER WATER OUTLET
5"
CONDENSER JACKET
REMOVABLE CONNECTION JOINT
COCK
COLD WATER PIPE
1'-10"
SPIRAL CONDENSER COIL
2'-6"
PRESSURE GUAGE
PERFORATED REMOVABLE BASKET
THERMOMETER
SPIRAL PERFORATED STEAM COIL

PLANT FOR TREATMENT OF BOSWELLIA SERRATA GUM-OLEO RESIN.



[To face page 28.

Photo. Zinco., May, 1918.—No. 2389-1-800

After removing the solvent the steam is let in through the perforated coil, and turpentine distilled off at 120°C.-130°C., after which, the steam is cut off and the rosin dried by raising the temperature of the steam-jacket to about 150°C., when it is run off in a molten state into the rosin tank or direct into barrels.

The residual gum, having absorbed a large quantity of the solvent, equal to about its own weight, is subjected to superheated steam, in order to recover the solvent. This is done by raising the temperature of the still to about 110°C. with the help of the steam jacket while superheated steam is passed through the perforated coil at a temperature of about 130°C.-140°C.

The disadvantatge of this method is that the solvent gets unavoidably mixed with the turpentine oil which alters its constants and this, though a disadvantage in some respects, does not alter its properties as a resin solvent. The reader is referred to page 22, in which he will find the analysis of turpentine prepared in bulk by using petroleum benzine as a solvent.

(ii) Steam-distillation followed by solvent extraction.

The alternative method is to first distil off the turpentine, by passing superheated steam at 120°C.-130°C. through the crude material, after loading the basket fitted in the solvent extractor, which is kept at a temperature of 110°C. with the help of the steam jacket. By this process there is no condensation of the water in the still, thus obviating absorption of water by the gum. The gum-resin is then treated by the solvent, and the solution of rosin run into the settling tank, as already described. The gum left in the basket is again treated with superheated steam to recover the solvent which it has absorbed after the turpentine has been driven off. The advantages of the latter over the former process, may be summed up as follows :—

(1) The oil obtained by the latter process, is free from solvent and therefore requires no further rectification.

(2) The gum and rosin being in a dry state on removal of the turpentine, can be easily acted on by the solvent. Any moisture contained in the raw material is also driven off in the process.

3) In the latter process, the solution is made up of rosin and solvent ; in the former case, turpentine is also present. To clear the rosin in the latter process requires one heating, in the former two heatings, and this is a disadvantage as repeated heating affects the colour of the finished product.

For want of superheated steam and the suitable plant, the latter process was not tried on a large scale, though the experiments conducted in the laboratory were a distinct success.

(*iii*) *Preparation of the products for the market.*

(*a*) Turpentine.

From the volatile nature of the oil, rectification in any form is not advocated, and this opinion is confirmed both by the Imperial Institute and by the Manager of the Shalimar Paint and Colour Works Company Limited, Calcutta. The flash point of the oil is already so low that any steps to lower it further, which would be the case if it is redistilled, are inadvisable.

(*b*) Rosin.

The points to be guarded against when dealing with the rosin are, overheating, which not only results in deepening an original good ruby-red colour, but also reduces its "strength," while every care must be taken to free it from fine particles of dirt, by allowing a sufficient period for settling in the tanks, while it is still in the form of solution in the solvent. It may be noted here, that in the case of *Boswellia* rosin, if this step of settling is omitted or not carefully carried out, it seems impossible to clean the rosin of this dust at any other stage of working.

(*c*) Gum.

From the nature of the process, the major portion of the impurities is found in the residual gum, only the fine dust having been carried away by the solvent. From repeated experiments, it was found that it is almost impossible to refine the gum on a large scale by dissolving it out in water or alkali and recover it in its original purity by evaporation in open copper vessels. It will be found advisable to put it on the market, in the same form as other similar gums, namely as flour. To reduce it to this state involves grinding and sieving through a fine series of sieves which hold up the fine particles of bark but allow the flour to pass through the mesh.

(*d*) Under-extracted gum.

By under-extracting the material, a gum containing 25 per cent.—30 per cent. of rosin was obtained on a large scale in the Forest Research Institute Distillery. From preliminary experiments, which were further confirmed by Mr. W. Raitt, Cellulose Expert, it was ascertained that this substance could be used as a subsidiary sizing material. If this, on further trial, proves to be correct it would be quite easy to cut

the extraction of the gum-oleo-resin at a fixed point in order to produce this mixed substance.

Part VI.—Industrial uses of the products and their commercial valuation.

1. *BOSWELLIA* TURPENTINE OIL.

As already remarked, the *Boswellia* turpentine oil consists mainly of dextro-pinene, and as such is as good as the best American and French oils of turpentine and its uses are the same as those of the latter.

With a view to corroborating the above statement, samples of turpentine prepared at the Forest Research Institute were submitted to the Imperial Institute, London, to the Ordnance Department and to Indian firms, whose reports are quoted in original below :—

(*i*) *Imperial Institute of the United Kingdom, the Colonies and India.*

Report on Turpentine oil prepared from the Gum-resin of Boswellia serrata *in India.*

The sample of turpentine oil prepared from the gum-resin of *Boswellia serrata*, which is the subject of this report, was forwarded to the Imperial Institute by the Forest Economist at Dehra Dun with letter No. D. O. 690-18, dated 16th April 1914. It was stated that the oil had been obtained by steam distillation of the gum-resin and that it had afterwards been fractionally distilled.

Description of Sample..

" *Boswellia* Turpentine made at the Forest Research Institute Dehra Dun." Weight about 2¼ lbs.

A mobile liquid oil with a slight greenish-yellow tinge and a sweet, agreeable odour.

Results of examination.

The oil being examined at the Imperial Institute was found to have the following constants :—

—	COMMERCIAL TURPENTINE OIL.		
	Boswellia turpentine oil.	American.	French.
Sp. Gr. at 15°-15°C.	0·8446	0·858 to 0·8770·	865 to 0·875
Optical rotation α D	+31° 24′	—9 to—14° 17′ (rarely slightly lævo-rotatory).	—29° to—33°
Ester Value, before acetylation . .	2·6	..	..
Ester Value, after acetylation . . .	36·4	..	..

On fractional distillation the *Boswellia* gave the following results :—

Fraction boiling at	Per cent.
153° to 160°C.	89
160° to 180°C.	11

The fraction boiling at 153° to 160°C. was re-distilled, and practically the whole passed over at 155°C.

For comparison with these figures it may be stated that 85 per cent. of American turpentine oil usually distils between 155° and 163°C. and 85 to 90 per cent. of French oil between 155° and 165°C.

It was found that the *Boswellia* turpentine oil readily dissolved resins such as colophony, dammar, sandarac and soft copal, but that varnishes prepared in this way dried more rapidly than those made with commercial turpentine oil and gave a less lustrous surface.

Commercial Value.

In order to obtain technical opinions as to the probable value of this *Boswellia* turpentine oil, samples were submitted to several turpentine merchants and distillers and varnish manufacturers likely to be interested in the product. The general opinion expressed was (1) that the oil is of a very good quality and closely resembles American turpentine oil, except as regards the smell, which is regarded as peculiar though not unpleasant, and (2) that the *Boswellia* oil could be successfully employed like ordinary turpentine oil in the manufacture of varnishes.

All the firms consulted thought that the *Boswellia* oil would be readily saleable in the United Kingdom. One firm stated that its commercial value should be approximately equal to that of American turpentine oil, though the difference in smell alluded to might constitute a slight drawback. Another firm considered that the oil would find a ready market in the United Kingdom if it could be sold at about 25 per cent. under the price of American turpentine oil, and a third firm valued it at about 30*s.* per cwt., with American turpentine oil at 37*s.* per cwt.

Remarks.

The rapid drying of this *Boswellia* turpentine oil, is possibly due to the remova by distillation in India of the higher boiling fractions. It was found at the Imperial Institute that a mixture of 10 parts of *Boswellia* turpentine oil and 1 part of the higher-boiling residual *Boswellia* " essence " which had been thus removed in India gave a somewhat better result in varnish-making than the turpentine oil alone. This view is further borne out by the fact that when the higher-boiling fractions were removed from commercial turpentine oil the resulting distillate yielded a quick-drying and somewhat inferior varnish to that obtained with the original oil.

It thus seems probable that a product even more closely resembling commercial turpentine oil could be produced by modifying the distillation of *Boswellia* turpentine oil so as to include a portion of the higher fraction, and that this oil would be more suitable for use in varnish manufacture than the oil represented by the present sample. As a guide to what is required it may be suggested that the *Boswellia* oil should be made to conform as far as possible to American turpentine oil in range of boiling point.

One of the firms of varnish manufactures consulted by the Imperial Institute pointed out the difficulty of expressing a definite opinion regarding the value of

turpentine oil from the testing of small samples in a laboratory, and expressed their willingness to make large scale trials with this *Boswellia* turpentine oil. If the product is likely to be procurable in large quantities for export it would be desirable to forward at least 2 cwt., to the Imperial Institute for submission to this and other firms who are willing to conduct large scale trials with it.

(ii) *Report by the Imperial Institute, South Kensington, London.*

The Turpentine Oil was submitted to two firms of varnish manufacturers for trial and commercial valuation, with the following results.

(1) The first firm stated that they had prepared for comparison two varnishes, one with genuine American turpentine oil and the other with the *Boswellia* turpentine oil, the remaining constituents in each case being the same, and had found that the *Boswellia* turpentine oil rendered the varnish slightly dull, whereas the varnish made with American turpentine oil remained bright. Equivalent quantities of *Boswellia* turpentine being considerably thinner. The drying and "face" of the finished varnishes were, however, practically identical.

The firm considered that as a substitute for American turpentine oil the *Boswellia* oil would probably be placed between French or Spanish and Swedish or Russian turpentine, but they were unable to assign a definite commercial value to it under present conditions.

(2) The second firm reported as the result of practical trials that this turpentine oil has a tendency to accelerate the drying of varnishes but that it detracts from their brilliancy and durability for exterior work. They stated that there is apparently no reason why *Boswellia* turpentine oil should not be utilized in the varnish trade.

Remarks.

The results of the investigation of this sample of *Boswellia* turpentine oil indicate that it differs from the preceding sample in containing a much larger percentage of the higher-boiling constituents, but that nevertheless the varnish prepared with it dries rather quicker than that made with ordinary commercial turpentine oil. The inclusion of the higher-boiling fractions does not appear to have any adverse effect on the quality of the varnish, so that it would seem unnecessary to remove these fractions in preparing the *Boswellia* oil for commercial use. The best rule on this point would probably be to make the product agree in range of boiling point with commercial American turpentine, as previously suggested in the report, dated the 4th May 1915.

There seems to be little doubt that this *Boswellia* turpentine oil could be successfully utilized for varnish-making in place of ordinary turpentine oil but it is not possible to state its exact commercial value until the product has been tried on a considerable scale.

(iii) *Report from the Superintendent, Gun Carriage Factory, Ordnance Depôt, Jubbulpore.*

I have had the sample of turpentine tested and have found it to be most satisfactory for paint work.

If you contemplate producing this in fairly large quantities, I suggest you address the Director of Ordnance Factories, 6, Esplande East, Calcutta, intimating the probable output, and probable cost per gallon.

(iv) *Report from Messrs. Turner Morrison and Company, Limited, Calcutta.*

The flash point of the *Boswellia* turpentine which has not been redistilled is 100·5°F[1].* I should point out that the colour of this oil would necessitate redistillation.[2]* As far as volatility goes, the sample is excellent and is better than any of the *Pinus longifolia* samples which have been submitted to us.

(v) *Report from the Superintendent, Loco. Department, Eastern Bengal State Railway.*

The turpentine has been tried and is very similar to other classes of this oil.

(vi) *Report from the Gun and Shell Factory, Cossipore.*

Specific gravity at 100°F. . . .	0·820
Physical properties	Normal, transparent, light yellow colour, about 10 per cent. distils before 310° and 323°F.

It was tested practically by mixing it with paint, it dried in under 24 hours and is therefore suitable for this purpose.

2. BOSWELLIA ROSIN.

Boswellia rosin, though different in its chemical composition from Pine resin, is similar to the latter, in physical characteristics. For this reason, except for the purpose of soap-making, it could be used for most other industrial purposes to which the pine rosin is put, for example, as an ingredient in varnishes, and in the manufacture of shellac.

Bulk samples of rosin were sent to the Imperial Institute London, Messrs. Angelo Brothers and the Shalimar Paint and Colour Works, Calcutta, for commercial valuation, and the reports received are as follows :—

(i) *Imperial Institute of the United Kingdom, the Colonies and India.*

Report on Boswellia *rosin from India.*

The *Boswellia* rosin dealt with in this report was forwarded to the Imperial Institute by the Forest Economist at Dehra Dun with a letter No. 313-18, dated the 17th March 1916. The sample reached the Imperial Institute on the 27th May 1916.

Description of sample.

The sample weighed 5·5 lbs. and consisted of four cakes, each measuring $9\frac{1}{2} \times 4\frac{1}{2} \times 1$ inches, of a golden brown, brittle, transparent rosin. The colour and appearance of the rosin was approximately that of grade "G" colophony.

N.B.—*[1] This sample was prepared without redistillation as suggested by the Imperial Institute.
*[2] This colour was due to the fact that the oleo-resin distilled in this case was a very old one which, owing to oxidation, had gone almost red.

Results of examination.

The rosin was analysed and gave the following results, compared with those obtained from the previous samples dealt with in the Imperial Institute reports on *Boswellia serrata* rosin from India dated the 31st May 1915.:—

—	Present sample.	Previous Samples.	
		A.	B.
Moisture per cent.	0·7	0·7	0·9
Ash per cent.	0·03	0·5	0·4
Melting point, C.	68·0	72·0	56·0
Acid value*	55·1	51·5	25·0
Saponification value*	90·2	92·0	66·0

* Milligrams of potassium hydroxide per gram of rosin.

Like the previous samples, the rosin was completely soluble in alcohol as well as in turpentine oil, and varnishes made by its solution in these liquids gave on drying a fairly brilliant but rather soft " coat " similar to that given by good grades of ordinary colophony, but less brilliant and softer than those yielded by dammar and other typical spirit varnish rosins.

The rosin was not completely soluble even on prolonged boiling in sodium carbonate solution, and as pointed out in the previous report could not be used as a substitute for colophony in making rosin soap or rosin size.

Remarks.

It is clear from the foregoing results that *Boswellia* rosin could only be used as a substitute for colophony, and then only in cases where the use of colophony does not depend on its complete solubility in alkaline solutions.

Technical trials will be required to determine precisely the commercial value of the *Boswellia* rosin, and these are now in progress. It does not seem likely, however, that the material will at best fetch higher prices than the colour grade " G " of colophony to which it corresponds, and which is at present worth 22*s*. per cwt. and is normally worth about 14*s*. per cwt.

(*ii*) *Further Report from the Imperial Institute of the United Kingdom, the Colonies and India.*

With reference to your letter No. 925-18 of the 4th ultimo and previous correspondence on the subject of *Boswellia* rosin, I have to inform you that a firm of importers to whom the rosin was submitted valued it at about £20 per ton in London (July 1916).

A firm of spirit varnish manufacturers described it as equal in all respects to American rosin and quite suitable for making certain qualities of spirit varnishes

They regarded it as about equal to grade "G" of American rosin, the market price of which was £21 to £22 per ton in London (July 24th).

As indicated in Imperial Institute Report of the 5th July last these prices are much in excess of those ruling for similar rosin before the war, thus grade "G" of American rosin in July 1914 was worth £17 to £18 per ton. Even this price was rather high, the normal value being about £14 per ton.

The *Boswellia* rosin has also been submitted for technical trials to a firm of varnish manufacturers, who state that they hope to report upon it at an early date, though their experiments have been hindered by urgent work for the Government.

(*iii*) *Report from Messrs. Turner Morrison, Agents for Angelo Brothers.* Boswellia *rosin.*

With reference to the correspondence ending with the letter from the Joint Manager of the Factory to your goodself, we have now pleasure to advise you that the tests we have made of your Rosin in our laboratory lead us to believe that it will be suitable for our purpose.* We are now prepared to make a more practical test on a somewhat larger scale.

We shall, therefore, be glad if you will at your earliest convenience kindly send us a couple of barrels of your Rosin, in order that an efficient practical trial may be made.

(*iv*) *Report by the Manager of The Shalimar Paint and Colour Works, Limited.*

The question of utilizing the rosin was discussed with the Manager, who pronounced it as equal in value to a good grade pine rosin for the manufacture of varnish.

(*v*) *Report by the Gun and Shell Factory, Cossipore.*

Specific gravity . . .	1·105
Solubility	Slightly abnormal, leaving a slight residue of woody matter.
Physical properties . . .	Powders well, colour dark, amber and on ignition leaves a slight residue.

It has been tried practically and is suitable for this Factory's requirements.

3. Boswelia Gum.

A small sample of the Gum was sent to the Manager of the Elgin Mills, Cawnpore, who pronounced it to be a possible substitute for farina.

* Note.—In the manufacture of shellac.

The report being encouraging, further samples were sent to the Imperial Institute, London, and to a Bombay firm for valuation, whose reports are given below :—

(*i*) *Report from the Imperial Institute, London.*

Report on Boswellia *gum from India.*

The three samples of *Boswellia* gum which are the subject of this report were forwarded to the Imperial Institute by the Forest Economist, and are referred to in Imperial Institute Report dated 5th July 1916. In a letter to the Imperial Institute, the Forest Economist referred to certain differences in the results of the examination of the gum as carried out by the Chemical Adviser at Dehra Dun and those obtained at the Imperial Institute. These differences related chiefly to the amount of resin found in the gums. The samples have therefore been re-examined at the Imperial Institute, with special reference to this point and to their suitability for use in the sizing and finishing of textiles.

Results of Examination.

The three samples were analysed with the following results :—

——	B(4)*a*.	B(4)*b*.	B(4)*c*.
	per cent.	per cent.	per cent.
Moisture	14·4	13·9	12·4
Ash	3·0	3·5	9·3*
Matter soluble in 95 per cent. alcohol . .	23·6	20·7	16·9*
,, ,, ,, ether . . .	20·9	17·3	11·6
,, ,, ,, cold water . . .	42·9	48·5	39·2
Specific gravity of a 10 per cent. solution at 15°=15°C.	1·025	1·023	1·022
†Viscosity of a 10 per cent. solution at 22°C	3·6	3·3	2·8

These results are compared in the following table with those obtained by the Chemical Adviser, the Imperial Institute results being given under the heading A, and those of the Chemical Adviser under the heading B. In order to eliminate

* The average of five determinations, which varied from 7·3 to 10·8 per cent. owing to the presence of heavy sandy matter it was difficult to obtain a really average sample of the material.

† As compared with 1 for water and 6·5 for soft Kordofan gum, 7·1 for Sudan Talh gum and 12·0 for hard Kordofan gum, determined under the same conditions.

discrepancies due to variation in moisture the results have been expressed in all cases on the dry materials :—

Specification.	Sample B(4)a.		Sample B(4)b.		Sample B(4)c.	
	A.	B.	A.	B.	A.	B.
	%	%	%	%	%	%
Ash	3·5	3·4	4·1	4·0	10·6	7·1
Resin (matter soluble in 95 per cent. alcohol).	27·6	not given.	24·0	10·2	19·3	21·2
Soluble gum (matter soluble in water).	50·1	Do.	56·3	not given	44·8	not given
Insoluble gum and dirt (exclusive of ash).	18·8	Do.	15·6	Do.	25·3	Do.
Matter soluble in ether (dry and free from alcohol).	24·4	9·0	20·1	9·4	13·2	18·3
				8·3		19·4

It will be seen from these figures that the results obtained at the Imperial Institute for matter soluble in alcohol and in ether (which for either solvent may be regarded as resin) are similar to those quoted in the previous Imperial Institute Report and do not agree with those found by the Chemical Adviser.*

Sizing Trials.

The following experiments were conducted at the Imperial Institute with a view to obtaining " jellies " from the gum—

(*a*) One part of the gum was allowed to stand over-night with 2 parts of water, and was then heated for 1 hour in a boiling water bath and allowed to cool. Only a pasty mass was obtained.

(*b*) One part of the gum was allowed to stand over-night with 10 parts of water, after which it was warmed on a water bath and allowed to cool. The liquid was freed from solid matter by being squeezed through calico, and the filtrate was concentrated on a boiling water bath, but no jelly was obtained.

(*c*) One part of the gum was heated under pressure with 5 parts of water at 133°C for 1½ hour, but yielded only a thin non-homogeneous paste of a brown colour.

From these experiments it appeared that this gum is much inferior to ordinary gum for use as a sizing material, but it was nevertheless submitted to one of the

* These differences in the resin content of the gum are only due to the lack of uniformity in the samples, as the solvents used were the same. [*Chem. Adviser*.]

most important British Calico Manufacturers. Their technical experts reported as follows :—

(*a*) " An attempt was made to obtain a solution in water at a strength of 4 : 10, but even with prolonged heating the result was merely a rough pasty mass (see sample A forwarded under separate cover.)

(*b*) " The gum was then heated in a closed bottle for an hour under a steam pressure of 6-10 lbs. This also failed to produce a smooth paste, though with undoubtedly better results as regards thickness. Sample B, forwarded under separate cover, shows this product at a strength of 2 : 10. It will be seen that this material is not sufficiently homogeneous to serve as a thickener or as a sizing agent.

(*c*) " It was found that a strong solution of caustic soda dissolved the gum, but there was no " body " in the product, as may be seen by a reference to sample C, forwarded under separate cover and subsequently neutralisation of the alkali with acid reprecipitated the gum.

(*d*) " The gum was found to be but little affected by weak solution of caustic soda, sodium carbonate or borax, and acetic acid was also without solvent action."

" As a result of these trials the conclusion arrived at by the experts was that the " insolubility " of this gum (*i.e.*, the presence of resin and gum insoluble in water) would prevent its employment for the purpose of sizing and finishing textiles."

(*ii*) *Report from Bombay, received through the good service of Mr. Wardlaw Milne.*

With reference to the *Boswellia* gum sent for test, we have made a few tests with the samples available. The chief possible uses of gum in the cotton trade are :—

1. Sizing.
2. Finishing.
3. As a thickening agent for cloth-printing.

There are no means available in India to test the gum for the latter, but we tried the small quantities for sizing and finishing. We had a difficulty in obtaining a thick solution by the usual method in use in Mills, *viz.*, mixing the gum with water and then boiling direct with steam passed into the water which, of course, increases the quantity of water by the condensation of the steam and results in a weaker solution. Better results were obtained by direct heating in double-cased kettles in which the steam does not come in contact with the water, and after sieving off the woody matter remaining, we obtained a fairly thick solution which does not carry weight, *i.e.*, will not hold China clay, French chalk or other weighing substance. Better results would be obtained perhaps by using bulk samples and if you could let us know the prices with about 2 cwts. of the material we could make a comparison on a commercial scale. There are possibilities in the gum for use in finishing where a firm finish without weight is required of in Tanjibs, but until a bulk sample is tried with a view to more exactly ascertaining its ability to fix weighing materials on the fabric, we would not like to definitely give an opinion as to its use in sizing or finishing where weight is required.

(iii) Report from Bombay received through the Director of Industries, Secretariat, Bombay.

Greaves Cotton & Co. write that so far they estimate the value of the gum at present at about Rs. 20 per cwt. laid down in Bombay. I understand this to refer to the finer sample.

4. Under-extracted Gum.

Gum in which about 30-40 per cent of resin is allowed to remain unextracted has been tried as a paper size. From the reports received, it is evident that this gum, dissolved in caustic soda, gives a fairly satisfactory size, though the exact process of preparing this size either from the resin direct or from the mixture of rosin and gum still remains to be finally worked out.

(i) Note on the use of Under-extracted Gum, by Mr. W. Raitt, Cellulose Expert.

The resin paste has an approximate composition according to Mr. Puran Singh as follows :—

	per cent.
Resin	40
Gum	45
Moisture	10
Sand and refuse	5

The rosin is almost wholly non-saponifiable and therefore differs widely in character from the pine rosin commonly used for paper-sizing. In practice, however, a large amount of the latter is purposely left in the "free" or uncombined condition in the size, and it is considered that a pine rosin size containing a considerable amount in the free state gives better sizing effects than a fully saponified size. Therefore, as practically the whole of the resin in this waste goes into solution as "free" resin it should prove a good sizing agent. The gum also, being wholly insoluble in water, should likewise have a sizing effect provided it can be precipitated from solution and apparently this can be done.

Both resin and gum go into perfect solution with 3 per cent. NaHO (*i.e.*, 100 resin waste+3 NaHO+ water sufficient to give the desired density). They are not fully soluble in soda carbonate, so caustic soda must be used but the amount required is very small. The solution can then be passed through a flannel or fine wire cloth filter to take out sand and extraneous matter. It can then be precipitated on the pulp or paper by adding alum to the extent of 4 per cent. on original weight of resin waste. Both resin and gum are thrown out of solution as a fine milky white precipitate, and the coagulating effect of the alum fixes them on the fibres.

Attached herewith are several strips of unsized filter paper which have been treated by first dipping in the solution and then in the alum. A comparison of the treated and untreated portions of the strips will show that the sizing effect is considerable. But I cannot regard such results as conclusive as we are unable for want of suitable plant, to reproduce all the conditions of a paper-mill where

the material is sized in the pulp form and where there may be a loss of sizing agent through its being abstracted by the water in passing over the machine wire. Neither can we imitate the fusing effect of the hot drying cylinders.

The results on these strips are, however, sufficiently good to warrant one of the mills being asked to try a parcel of this resin-waste say—100 lbs. A copy of the note and one or two of the attached strips should be sent to the mill manager as a guide for his proceedings. If he finds it useful it will also be cheap, for the material is a by-product and the amount of chemicals required for its treatment is much less than in the case of pine resin.

(*ii*) *Report on tests carried out by the Titaghur Paper Mills Co., Ltd., with the* Boswellia serrata *Under-extracted Gum for Paper Sizing.*

The sample very kindly sent us by Mr. R. S. Pearson, has been submitted to tests under practical working conditions with the following results :—

The sizing solution was made up by dissolving 100 lbs. Resin with 3 per cent. of 77 cent. Caustic Soda in 90 gallons of water.

Laboratory experiments had indicated that a high percentage of the Resin would be necessary for sizing purposes, so it was decided to divide the solution between two beaters of stuff.

No. 1 This beater contained approximately 500 lbs. of stuff. The quantity of the sizing solution added was 40½ gallons, equal to 45 lbs. of resin.

The solution was well beaten into the pulp, then 25½ lbs. of Alum added.

After this was thoroughly mixed, the stuff in the beater gave a distinct acid reaction.

The sizing results in the finished paper can only be considered fair.

Sample sheets accompany this report.

The quantities used represent Resin 9 per cent., Alum 5·1 per cent.

No. 2. This beater contained approximately 550 lbs. of stuff. The quantity of sizing solution used was 49½ gallons equal to 55 lbs. of resin.

The solution as before was well mixed with the pulp, then 55 lbs. of Alum added.

In this case there was only a slight acid reaction.

The actual result in the sizing of the paper was slightly better than trial No. 1.

Sample sheets accompany the report.

The quantity used represents 10 per cent. Resin and 4·63 per cent. Alum.

Our average consumption of Naini Tal Resin works out 2 per cent. per ton of paper and Alum 4 to 5 per cent.

Before any general conclusion can be drawn as to whether *Boswellia serrata* can be utilized for sizing paper, it will be necessary to make extended trials.

It is possible that the high percentage of resin we found necessary would lead to trouble with wires and felts and also cause sticking at presses and calenders.

In the case of White Paper, this excess of resin if actually found necessary after extended trials would, I fear, lead to early yellowing and rapid deterioration.

We had some difficulty in getting the solution through the sieves and we found a good proportion of dirt and grit.

Samples of paper sized with our own size accompany the others for comparison.

Part VII.—Financial aspect of the business.

1. Profit and Loss Account.

No definite figures are available as to cost of working, as a suitable plant was not available, nor has any work of exactly the same nature been carried out up to date. In framing an estimate of working, past experience of pine oleo-resin distillation and solvent extraction of fats and oils have been taken into consideration, while the cost of tapping and collection is based on actual working in Gwalior State and on the experiments carried out in the North Khandesh Division. The rates for turpentine are based on pre-war rates for a good grade of American oil and this may be taken as a correct assumption, in view of the favourable reports received on *Boswellia* turpentine. The present rate in India for good turpentine is Rs. 5-8 per gallon, while the price fixed in the estimate is Rs. 2-8 per gallon. From reports received from the Imperial Institute and other sources, the rosin may be classed as "G" grade colophony, which in August 1917 sold at Rs. 16 to Rs. 17 per maund and may be put at Rs. 10 per maund after the war. To fix a price for the gum is a more difficult problem, as it is a new product, not unlike gum arabic, but probably not of the same value on account of 7 per cent. of bassorin, which it contains. Gum arabic may be put at Rs. 40 per maund, so that *Boswellia* at Rs. 5 per maund is probably a very low estimate.

Based on the above data, the following estimate of profit and loss has been framed :—

Cost of dealing with 100 maunds of gum-oleo-resin.

	Rs.	A.	P.
1. Cost of collecting 100 maunds of crude "drip" at Rs. 5 per maund	500	0	0
2. Cost of distillation :—			
(1) Loss of 5 per cent. of Benzine (Sp. Gr. = ·74) at Rs. 2 per gallon on 100 maunds of resin	112	0	0
(11) Steam distillation, recovery of solvent from both stills per 100 maund, at Rs. 0-8-0 per maund	50	0	0
Total	662	0	0
3. Labour and supervision at Rs. 0-8-0 per maund per 100 maunds of resin	50	0	0
4. Over head charges at 2 annas per maund per 100 maunds of resin	12	8	0
5. Depreciation at 10 per cent. on plant per 100 maunds, assuming its cost to be Rs. 100,000 and its capacity 60,000 maunds of resin per annum	16	12	0
6. Interest each year at 6 per cent. on Rs. 50,000 working capital per 100 maunds	5	0	0
7. Packing, insurance, etc., 4 annas per maund per 100 maunds of resin	25	0	0
8. Miscellaneous charges	8	12	0
Grand Total	780	0	0

Receipts.

	Rs.	A.	P.
Turpentine (yielded 8 per cent. Sp. Gr. ·84) 77 gallons at Rs. 2-8	192	8	0
Rosin 55 maunds at Rs. 10 per maund (yield 55 per cent) .	550	0	0
Gum (yield 22 per cent.) 22 maunds at Rs. 5 per maund .	110	0	0
TOTAL .	852	8	0

This works out at a profit of Rs. 72-8 per 100 maunds or a profit of 11·6 annas per maund.

Part VIII.—Conclusions.

The conclusions arrived at after a somewhat prolonged investigation are that the preparation of *Boswellia serrata* products may lead to an important industry, though from a perusal of the data collected and given in the preceding pages, it is evident that it will be necessary to confirm the figures of cost of manufacture in a single unit plant before undertaking such an enterprise on a large scale. As regards the prospects of finding a ready market for the turpentine and rosin, there seems to be no question of doubt ; it is somewhat difficult to predict the market value of the gum, though there is little doubt that at Rs. 5 per maund, which is the figure given in the estimate, it should find a ready sale.

From the statements given in Part II it is clear that the outturn of the gum-oleo-resin is considerable, while the results of tapping experiments carried out on a large scale are fully confirmed by the operations in the Gwalior State, and no apprehension is entertained on this score.

Under present conditions it is almost impossible to frame any estimate for plant, the figure given is based on pre-war experience.

Taking into consideration all factors governing the prospects of such an industry, there can be little doubt that its potential possibilities are very considerable.

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THE INDIAN FOREST RECORDS

Note on the preparation of Turpentine, Rosin and Gum, from *Boswellia serrata* (Roxb.) gum-oleo-resin.

by

R. S. PEARSON, F.L.S., I.F.S.,
Forest Economist,

and

PURAN SINGH, F.C.S.,
Chemical Adviser,
at the Forest Research Institute, Dehra Dun.

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